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Annex C to Experimental Plan for Assessment and Measurement Of Some Human Factors Issues in the Control of Offshore Helicopters Using Automated Dependent Surveillance

Air Traffic Controller Performance as a Function of Varying Times to Loss of Separation Within Different Densities of Helicopter Air Traffic

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EXECUTIVE SUMMARY

Under an FAA Research Grant, Embry-Riddle Aeronautical University's ATM Research Laboratory (EARL) has been carrying out research into the Human Factors aspects of the use of Automated Dependent Surveillance-Broadcast (ADS-B). This paper describes the first in a series of experiments to investigate these issues. The second series of experiments is described in a companion paper (see Annex D). Although some of the background information is the same for both experiments, and some of the data obtained from this experiment are used in the second experiment, the actual experiments and their outcomes are different; therefore, each paper is presented as a complete report.

Currently, there are more than 600 helicopters operating in the Gulf of Mexico in good weather. Each of these aircraft may fly more than 10 flights per day in good weather. However, when the weather is poor, the number of flights is reduced to less than 2% of the good weather figure. The reason for this is the fact that, because there is no radar coverage in the Gulf of Mexico, the aircraft must follow cumbersome procedural routes. The disruption and delays caused by these factors has been estimated to cost the oil industry and the helicopter operators $300,000 per hour.

This document details an experiment that forms part of the research into the control of helicopters operating offshore in the Gulf of Mexico. The intention of the series of experiments is to determine whether ADS-B displays can be used in the Gulf of Mexico to provide "radar-like" control service to replace the procedural control mentioned above. It is also intended to provide a first approximation of the workload issues that might be associated with the number of helicopters that could make use of the service. Since one of the major air traffic control tasks involved in using ADS-B for the control of helicopters is conflict detection, this task is the main dependent variable used in the study. Therefore, the experiment focuses on conflict detection abilities while using ADS-B to display the helicopter traffic.

This experiment provides metrics to evaluate controllers providing a 'radar like' service to helicopters flying direct routes in the Gulf of Mexico; the subjects involved are upper-level student controllers from Embry Riddle Aeronautical University. The time to detect a conflict is measured as the dependent variable, while the dynamic density of helicopter traffic and the time to loss of separation are varied as the independent variables. The dynamic density of the helicopter traffic is defined as the number of helicopters in a given volume of airspace. The time to loss of separation is a measure of the time from the moment that two aircraft turn into each other, to the time that they lose 5 miles of horizontal separation. Using a simulated ADS-B display to present the visual information, the experiment assesses the relationship between helicopter traffic density and the time to loss of separation on the workload and efficiency of the controller detecting conflicts.

Results indicate that the ADS-B display is more than adequate to control the amount of traffic in the experiment. However, the results also indicate that there may be workload issues associated with the number of helicopters that can be accommodated using the ADS-B display. These issues may form the basis for further research.

1. BACKGROUND

1.1 As part of the EARL Research grant from the FAA, research is being conducted into the use of ADS-B by controllers for helicopter traffic in the Gulf of Mexico. As there is almost no radar coverage of the helicopters operating off-shore, the IFR service provided when conditions are IMC is limited to a strict procedural system. This system has been enhanced in recent years by the use of a grid of reporting points over the ocean, but it is still extremely restrictive. During normal VFR operations, as many as 6,000 flights per day can take place. When IFR procedural rules are in place, this figure drops to around 100 flights per day. Effectively, the 600 or more helicopters servicing the oil rigs and platforms in the Gulf are grounded when the weather conditions become IMC.

1.2 To assess the problem, visits were made to Houston Center and New Orleans TRACON and a meeting of the Helicopter Safety Advisory Committee (HSAC) was attended. At Houston Center, there is very little helicopter traffic when the weather is good and the oceanic control sector provides a flight following service or procedural control service to the few helicopters that call as part of the overall oceanic control task. When the weather deteriorates and the helicopters are forced to fly IFR, up to 2 separate sectors may be manned to provide procedural control to the helicopter traffic. Similarly at New Orleans TRACON, a separate control position provides service to helicopters under certain IFR conditions.

1.3 The concerns over the inefficiency of some of the services in the Gulf of Mexico have led to attempts to improve the service. As stated above, the procedural system has been improved, and there have been trials for several years based on new avionics that are now available such as ADS. ADS has been used in Alaska, albeit in a far less intensely flown area, to resolve the problems of lack of radar cover and to provide the aircraft with Cockpit Display of Traffic Information (CDTI). There is some reluctance from the helicopter operators to try to equip small helicopters with the newer avionics. This is not only due to the costs associated with them, but also the lack of space and power supplies in the cockpits of the aircraft. Therefore, a solid cost-benefit case would need to be made for the operators to equip their aircraft with these avionics. The case would have to be made both to large international helicopter operators and to the small independents. Even with a strong business case, it is unlikely that all aircraft would equip these avionics. Therefore, any future system would need to accommodate mixed equipage.

1.4 One of the major underlying issues with ADS display technology involves the question of how it affects an air traffic controller's ability to detect conflicts. Conflicts, or losses of separation, are defined by the loss of 5 miles of horizontal separation or 1,000 ft. of vertical separation. Naturally, there are many factors which affect the controller's ability to carry out the task of detecting possible conflicts. Two of these factors will be manipulated in the current research in order to determine the potential effect they have on the conflict detection ability of the air traffic controller using ADS displays.

2. INTRODUCTION

2.1 At present, the local air traffic services within the Gulf of Mexico are provided by several air traffic control units. These vary from the large, well-equipped TRACON at New Orleans through the smaller radar equipped airports like Houma to busy non-radar units such as Patterson and to the large number of landing sites with almost no facilities. Houston Center provides the air traffic service for the majority of the area of the Gulf of Mexico and has a dedicated oceanic sector, as well as a single helicopter oceanic sector in cases of sufficient demand for IFR service. The Houston sectors operate with their displays set to show their area of responsibility that stretches from the Mexican airspace boundary North to the Gulf shore and from Brownsville in Southern Texas, east to the Mississippi delta. The 600 aircraft in the helicopter fleet carry out their 4,000-6,000 flights per day within the area covered by this display.

2.2 This paper describes an examination of one of the issues of the provision of a radar-like service to helicopters in the Gulf of Mexico. Air traffic controllers must detect conflicts before a loss of separation occurs. A conflict occurs when two aircraft are on a course in which they will eventually lose separation. A loss of separation, as previously mentioned, is defined by a distance of 5 nm of horizontal separation between the aircraft, or 1,000 ft. of vertical separation. Naturally, the time between when the aircraft turn into each other and the time when a loss of separation occurs can vary. It is quite possible that the amount of time required of the controller to detect a conflict will change as a function of this variable time interval. In addition, the controller must be able to perform these duties in various traffic densities. Traffic density, for the purpose of this research, is defined as the proximity of the aircraft. Essentially, it is how tightly-packed the aircraft are. These two variables are used in this experiment in order to quantify the conflict detection capability of the controller while using a simulated ADS display in a moderately heavy traffic environment.

3. STATEMENT OF PROBLEM

3.1 The issues raised by the requirement to provide control of helicopter traffic in the Gulf of Mexico that pertain to this study are as follows:

- a There are more than 600 helicopters operating offshore in the Gulf with up to 6,000 flights per day (many of which are short platform-to-platform flights).
- b Of the 600 or more airframes, only approximately 100 are equipped with avionics to allow IFR flight, although this number could be expected to rise to 200 if there were a good cost benefit case made to the operators.
- c For some of the helicopters, it is physically impossible to upgrade the avionics to provide ADS.
- d Air traffic controllers must detect conflicts that have different times to loss of separation.
- e As traffic density increases, so too should the workload of the controller; and this in turn should affect the controller's ability to detect conflicts.
- f Using a simulated ADS display, the Conflict Detection (CD) capabilities of the controller for helicopter environments of varying Traffic Densities (TD) and Times to Loss of Separation (TLS) needs to be investigated.

4. REVIEW OF RELATED LITERATURE

4.1 Conflict detection

a Signal detection theory (SDT) is often used to describe and classify how humans detect stimuli. It is based on the division of stimuli into signals and noise, also referred to as states of the world. The theory then divides two responses made by observers of the stimuli into the two categories of: “yes, a signal is present,” or “no, a signal is not present.” Combining these responses to the two states of the world provides the ability to generate four possible outcomes. Each outcome has a probability of occurrence. The four possible outcomes consist of hits, misses, false alarms and correct rejections. Hits are the result of a present signal that receives a yes acknowledgment. Misses occur when the observer acknowledges that there is no stimulus present, when there actually is a present stimulus. False alarms occur when there is no signal present, but the observer indicates that there is a signal. Correct rejections occur when the observer indicates that there is no signal, and there actually is no signal (Parasuraman et al., 2000).

b The concept of SDT was initially used to objectively measure the ability of electronic receivers to detect radio signals in which there was a considerable amount of noise (Peterson, Birdsall, & Fox, 1954). Later, it was used to describe the ability of humans to detect signals at the threshold level of signal detection (Tanner & Swets, 1954). In 1966, Green and Swets wrote a popular book describing the modified theory. The use of SDT was then applied throughout psychology and other disciplines to many decision-making tasks that involved perception and cognition (Swets & Pickett, 1982). There are many situations to which SDT can be applied since it has the advantage of providing a common metric across these areas. Such areas include the analysis of human, machine, or joint human-machine performance (Parasuraman, 1985).

c One of the major underlying assumptions of SDT is that the person doing the detection must do so in a noisy environment. In the case of air traffic control, signal detection often involves the detection of conflicting aircraft. As there are typically other aircraft on the ATC display that are not in conflict, these additional aircraft would be considered as noise. These noisy, distracter aircraft may be mistaken for a conflict target to be detected. It is therefore more difficult to search for actual conflicts when the number of distracter aircraft increases (Rosenholtz, 2001). Duncan and Humphreys’s (1989) provide a guideline for search when distracters are present. As cited in Rosenholtz (2001), they state that, as the target becomes more distinguishable from the distracters, or as the variability of the distracters decreases, search becomes easier.

d There are many other factors besides noise that affect the controller's ability to conduct this task. One such factor that could potentially affect controller conflict detection ability is the trajectory at which aircraft approach each other. The various trajectories that aircraft on the display are flying must be mentally estimated. The trajectories are estimated by the use of aircraft symbols, past histories, and other flight path representations in combination with the information of the flight that is given by data blocks such as airspeed and altitude. Accurate conflict detection helps ensure that controllers are remaining responsible for the safety of aircraft in their sectors (Remington et al., 2000).

e Research has shown that as traffic density increases, the air traffic controller may need to search more aircraft pairs. In addition, the angle of convergence for conflict pairs and the length of time before a conflict occurs both have an effect on the way that the controller searches the display for conflicts. For instance, if the conflict angle is increased, the time required for conflict judgments of these trajectories increases. In addition, greater distances between potential conflict targets could increase the difficulty of detecting these aircraft as being in conflict (Remington et al., 2000).

4.2 Conflict resolution

a Air traffic controller conflict resolution performance is very difficult to measure because of the dynamic nature of the tasks involved. Since controllers are encouraged to incorporate their own strategy of handling traffic, variability in controller performance is inevitable. Conflict resolution may involve a change in speed for one or both aircraft, or it can involve a change in altitude or heading. In addition, the controller may notice a potential conflict situation, but choose not to act on it until later. In addition, controllers often vary in their strategy of aircraft sequencing. When comparing the conflict resolution performance of multiple air traffic controllers, one of the major findings has been that there is high variability from controller to controller in the location at which aircraft end up. The effectiveness of the various control strategies observed among controllers is difficult to measure because separation between aircraft is almost always maintained. For this reason, ATC performance measures should focus on activities that occur over a long time period, as opposed to activities that occur within small time frames (Bruskiewicz et al., 2000).

b It is also difficult to measure air traffic controller conflict resolution performance as it applies to workload measurement because covert, or cognitive, actions are not often accounted for. It is very difficult to measure cognitive actions. Research attempting to measure it often relies on subjective accounts of cognitive processing that are acknowledged by the controller participant after a control strategy has been performed. Cognitive actions typical in ATC simulations include the review of aircraft speeds, positions, and directions. Although the controllers may do this throughout the entire simulation, they only physically act on it at a single certain point. It is at that point that physical, observable actions such as keyboard entries are observed (Bruskiewicz et al., 2000).

5. METHODS

Participants

5.1 The current study consisted of a sample of upper level air traffic management students from Embry-Riddle Aeronautical University. The criterion for participation included the completion of at least two courses in air traffic control incorporating practice using conventional radar displays with some exposure/knowledge of ADS technology. A total of 6 participants were observed during this experiment.

Simulations and Equipment

5.2 The following equipment was used during this study:

a An ATC simulator with software capabilities to vary the distances between conflict targets and dynamic densities of traffic within the sector.

b Data recording of the time at which conflict detection occurred.

6. DESIGN

6.1 In a within-subjects design, participants were tested under four simulations on their ability to detect conflicts. Thus, the dependent measure under study was “Conflict Detection” (CD). Two independent variables were involved, including Traffic Density and Time to Loss of Separation. The different levels of Time to Loss of Separation were consistent throughout each level of Traffic Density. Therefore, each simulation contained a single level of Traffic Density and all three levels of Time to Loss of Separation. In those instances where the conflict was not detected at all, the time to conflict detection was set at the maximum. In other words, the time to detection equalled the time from the start of the conflict to the time when the loss of separation occurred.

Traffic Density (TD)

6.2 The density of the traffic is defined by how tightly packed the aircraft within the sector are. Traffic volume was held at a constant 18 aircraft for each level of this variable. This has been determined to be a moderate number of aircraft within a sector with regard to the amount of workload that this number of aircraft imposes on the controller. There were four levels of Traffic Density (TD), which constitute the four simulations. In one condition, the aircraft were scattered throughout the entire radar screen with a total distance of 50 nm visible within the display. This was considered a “Very High” amount of TD. In another condition, the aircraft were scattered throughout a flight environment of 75 nm, thus decreasing the density of the traffic. This was a “High” level of TD. The third level of this variable decreased the density of the traffic by providing a displayed flight environment of 100 nm, which was considered a “Medium” level of TD. The final condition contained an ADS screen on which the 18 aircraft were scattered with a density which was “Low” by incorporating 125 nm within the display.

Time to Loss of Separation (TLS)

6.3 The ability of the ATC participants to detect conflicts was measured under three levels of an independent variable, TLS. These levels contained 10, 12.5, and 15 minutes between the time that the conflict was introduced and the time that the loss of separation actually occurred. Each of these levels of TLS was present in all levels of TD. There were two conflict situations for each TLS per TD scenario (simulation). Thus, there were a total of six conflicts that should have been detected per simulation.

6.4 The framework for this study was as follows:

		TLS	
	10 min	12.5 min	15 min
TD 50 nm			
TD 75 nm			
TD 100 nm			
TD 125 nm			

6.5 Several aspects of this study were controlled. A consistent number of aircraft in the flight environment were displayed. This number of aircraft remained constant at 18. Conflicts occurred in random locations for every condition. The angles of conflict consisted of aircraft approaching each other at 45° and 90°. Entirely new traffic patterns were developed for the levels of TD and TLS so that any practice effect would be minimized across the trial runs.

6.6 Counterbalancing of participants occurred in this within-subjects design, so that the order in which the scenarios were presented was randomized.

6.7 In addition to the objective measures of CD that were recorded, subjective workload measures were taken. These measures were provided by the administration of the NASA-TLX workload rating scale, which is a validated measure of participant workload.

7. PROCEDURE

7.1 Controller participants were first briefed as to their purpose in the experiment. This took approximately 2 minutes.

7.2 The controller was then seated at the ATC simulator to begin a practice trial. The practice trial lasted 20 minutes. The practice trial was similar to the following experimental trials. It contained a moderate level of TD (Medium), and all three levels of TLS occurred throughout the trial. Following the practice trial, a 5-minute break was available to the controller participants.

7.3 The participants then began the first of four experimental trials. Each experimental condition lasted 20 minutes. After every experimental trial, each participant received the NASA-TLX. This took approximately 5 minutes to complete.

7.4 A 5-minute break was provided after every experimental condition.

7.5 After the final experimental trial was completed, the participant was debriefed, at which time an explanation of the intent of the experiment was provided, and any questions regarding the study were answered. Debriefing took approximately 5 minutes.

7.6 With the briefing session included, plus each 20-minute trial (practice and experimental), each 5 minute break, and the 5 minute debriefing session, the total average time of the study per participant came to 2 hours and 32 minutes.

8. METRICS

Objective Metrics

8.1 Participants were required to detect conflicts at varying levels of TV and TLS. Whether or not a conflict was detected was recorded and additionally, if detected, the amount of time taken for the participant to detect that conflict. Conflicts that were not detected were assigned a maximum value as described earlier,

METHODOLOGIES – Objective Metrics

8.2 Conflict detection was recorded as the time at which the controller clicked on the two aircraft in conflict. The amount of time taken by the controller to detect the potential conflict situation was measured from the time that the aircraft began a heading that would result in this conflict situation, to the time that the controller clicked on the aircraft.

Subjective Metrics

8.3 The NASA-TLX was provided at the conclusion of each experimental condition, with the purpose of obtaining subjective measures of controller workload.

METHODOLOGIES – Subjective Metrics

8.4 The NASA-TLX asked participants to rate demand levels on a scale ranging from LOW to HIGH. The demand domains consist of MENTAL, PHYSICAL, TEMPORAL, PERFORMANCE, EFFORT, and FRUSTRATION. Pair-wise comparisons of these demand domains were then made by the participant, during which time the demands that provided the most significant source of variation during the tasks at hand were circled. Workload calculations were then made by the researcher based on these responses.

9. HYPOTHESES/INTENDED RESULTS

9.1 It was hypothesized that lower levels of Traffic Density would result in lower conflict detection times

9.2 It was hypothesized that lower times to loss of separation would result in shorter conflict detection times.

9.3 An interaction effect for the TD and TLS variables was expected, so that the level of TD which would result in optimal performance would be dependent on the level of TLS incorporated.

10. ANALYSIS OF RESULTS

10.1 A repeated-measures analysis of variance (ANOVA) was conducted on the Traffic Density and the Time to Loss of Separation variables, as well as an interaction effect between these variables. The following tables provide a summary of the analysis.

Tests of Within-Subjects Effects

Dependent Variable: Conflict Detection Time

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1744490.861(a)	11	158590.078	5.323	<.001
Intercept	29539959.959	1	29539959.959	991.559	<.001
td	797823.836	3	265941.279	8.927	<.001
tls	834799.028	2	417399.514	14.011	<.001
td * tls	153929.407	6	25654.901	.861	.525
Error	4587881.844	154	29791.441		
Total	35053845.000	166			
Corrected Total	6332372.705	165			

a. R Squared = .275 (Adjusted R Squared = .224)

As the table makes clear, there is a significant difference between the time to detect a conflict and both the aircraft density variable and the time to loss of separation variable. Both of these are in the expected direction. That is, as the density of aircraft increases, the time to conflict detection increases. And, as the time to loss of separation increases, there is a decrease in the conflict detection time. These are both significant at a.99 level. This means that we can be over 99% certain that the difference observed is not due to chance. This is in fact the expected result if the ADS display is providing information that is similar to that shown by a normal radar display. In other words, the controller's were reacting in a normal fashion to the independent variables that were manipulated in the experiment. However, the results did indicate that there could be some important workload issues if many helicopters were to take advantage of the ADS-B service; these results that will be discussed in more detail below.

In order to more closely analyze the specific levels of comparison for the independent variables and their effect on the dependent variable, the following table provides a pair wise quantitative summary of mean comparisons for the levels of Traffic Density:

Multiple Comparisons

Dependent Variable: Conflict Detection Time
Tukey HSD

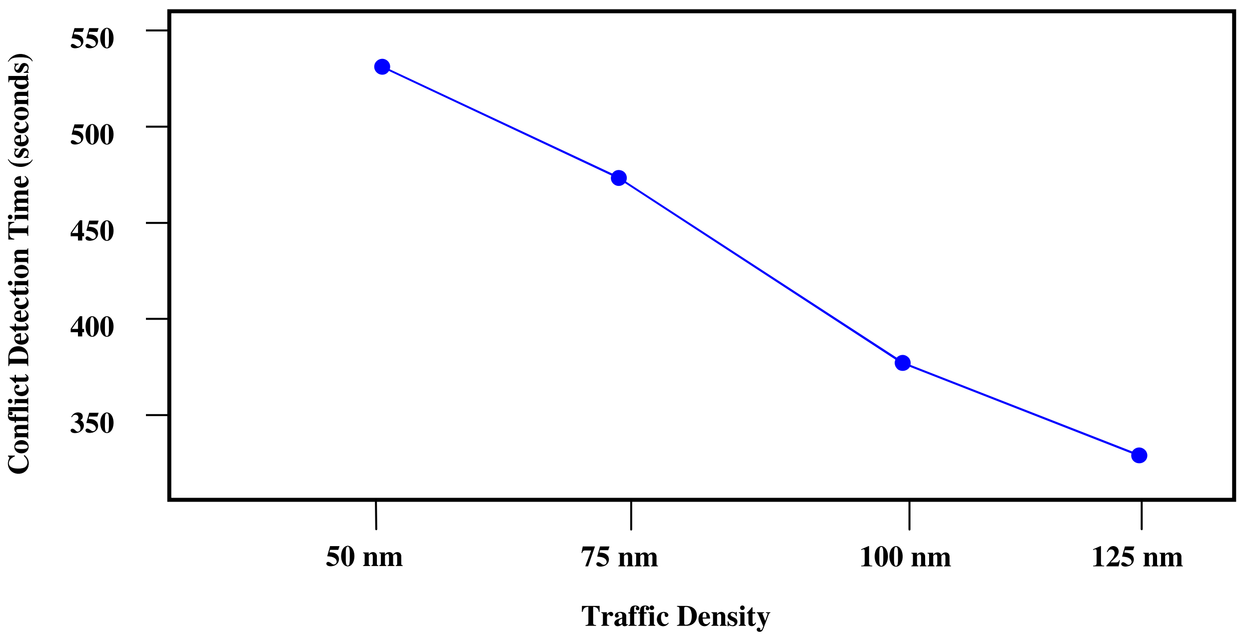
(I) Traffic Density	(J) Traffic Density	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
50	75	58.44	39.087	.443	-43.08	159.96
50	100	153.53(*)	38.607	.001	53.26	253.81
50	125	165.48(*)	37.386	<.001	68.38	262.59
75	100	95.10(*)	38.607	.070	-5.18	195.37
75	125	107.05(*)	37.386	.024	9.94	204.15
100	125	11.95	36.885	.988	-83.85	107.75

Based on observed means.
* The mean difference is significant at the .10 level or higher.

The pair wise comparison points out some interesting differences between the levels of traffic density. As we can observe from the table, there is no significant difference between the traffic density from 50 to 75 nautical miles. This could be an indication that when the density reaches a certain critical level (75 in this case), that higher density levels are essentially the same from a controller reaction standpoint; this would be an important finding from a workload point of view that might suggest limits to the number of helicopters that could be controlled under ADS. However, this conclusion would definitely require further research. When the comparison is between 50 and 100 nautical miles, there is no doubt about the result. Between these ranges, there is a significant decrease in the time to conflict detection, so that for these particular conditions, the controller is finding it easier to identify potential conflicts. This certainly indicates that the ADS display is providing sufficient information to the controller for these ranges. At the other end of the scale, the same phenomena is present in the 100 to 125 nautical mile range difference; that is, there is no significant difference between these ranges. This could have the same explanation as in the earlier case; that is, when a certain critical dispersion level is reached, the controller reaction level remains essentially constant.

A graphical presentation of the results shows the nature of the relationship more clearly. Therefore, the following plot demonstrates mean differences for the levels of Traffic Density:

Estimated Marginal Means of Conflict Detection Time across the four levels of Traffic Density



The plot clearly shows the nonlinear nature of the relationship at the extremes. It also makes clear the significance of the relationship in the intermediate ranges. And, as pointed out earlier, and based on the hypothesis of the experiment, the ADS display appears to be providing information to the controller that is similar to a radar display in the intermediate ranges.

To further analyze the effect of the independent variables, the following table provides a summary of mean comparisons across the three levels of the Time to Loss of Separation variable:

Multiple Comparisons

Dependent Variable: Conflict Detection Time
Tukey HSD

(I) Time to Loss of Separation	(J) Time to Loss of Separation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
12.5 min	10 min	47.01	32.336	.316	-29.52	123.53
15 min	10 min	168.39(*)	33.240	.000	89.72	247.05
15 min	12.5 min	121.38(*)	32.963	.001	43.37	199.39

means.
* The mean difference is significant at the .10 level or higher.

As in the earlier traffic density variable, there is no significant difference in conflict detection time at the lower end of the time to loss of separation variable. Again, this could be a lower bound to controller reaction time and therefore suggestive of the fact that conflicts are more easily identified from this point onwards. In other words there would be no significant further decrease in detection time if the time to loss of separation were lowered still further. However, and also similar to the traffic density variable, there is a significant difference in the intermediate range of the time to loss of separation variable. This finding also supports the hypothesis that controllers find it easier to detect conflicts when there is less time to loss of separation, but that the longer-term conflicts present more subtle and difficult workload problems.

Since the analysis of the interaction of Traffic Density and Time to Loss of Separation was not found to be significant, no mean comparisons were conducted.

10.2 A one-way analysis of variance was conducted on the NASA-TLX workload measures collected from five of the participants during the experiment. The test first asks participants to place a marking on a low-to-high scale line that represents the magnitude of that particular factor for the task that was just performed. This is done for the factors of Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration. These factors are operationally defined on a separate sheet. The participants are then asked to fill out a pair wise comparison sheet, which lists the previously mentioned factors side by side, and the participant is required to circle the member of each pair that provided the most significant source of variation in the task just performed. The responses are then entered into a computer software program, which generates a raw rating and a weight assigned to that rating for each factor. The raw rating and the weight are then multiplied, and an adjusted rating is computed. The actual workload rating for that individual during the task is the sum of the adjusted ratings.

No significant differences were found at the .10 alpha level between the levels of the variables studied for the subjective workload measures taken. The following tables provide a summary of this analysis.

Descriptives

Workload

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
50nm	5	3.67540	1.864968	.834039	1.35974	5.99106	1.844	6.380
75nm	5	3.43980	1.687172	.754526	1.34490	5.53470	1.178	5.733
100nm	5	2.65340	1.297513	.580266	1.04232	4.26448	1.200	4.380
125nm	5	1.64040	1.079258	.482659	.30032	2.98048	.400	3.004
Total	20	2.85225	1.611579	.360360	2.09801	3.60649	.400	6.380

ANOVA

Workload

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12.655	3	4.218	1.839	.181
Within Groups	36.692	16	2.293		
Total	49.347	19			

11. CONCLUSION

11.1 The study investigated the workload levels of the controller as simulated in an ATM environment incorporating ADS-B display technology. Through the careful manipulation of TD and TLS, these workload levels were compared to the controller's ability to handle potential conflict situations as they may occur in the currently-existing Gulf of Mexico situation, and as it may exist in the future with the addition of ADS-B in an increasing number of helicopters.

11.2 The research indicates that the controller's ability to quickly identify conflicts is a function of varying Traffic Densities and Time to Loss of Separation. The lack of significance for the interaction of these two variables means that these factors individually play a role in the conflict detection capability of the controller, but that there is no combined effect.

11.3 The Traffic Density variable showed that the 125 nm condition resulted in the lowest mean conflict detection time. However, this was not significantly lower than the 100 nm condition. Although it is not statistically certain as to whether the 125 nm condition actually resulted in better performance than the 100 nm condition, this level of TD will be incorporated in the subsequent experiment, which involves the manipulation of the ADS update rate on the controller display.

11.4 The manipulation of the TLS variable resulted in conflict detection times lowest when the TLS was lowest. It is quite possible that this is due to the fact that the closer proximity of forming conflicts allowed for greater ease in their recognition. These same levels of TLS will be incorporated into the subsequent experiment, with the purpose of determining if results vary with the manipulation of the ADS update rate.

11.5 Surprisingly, the workload measures taken did not result in significant workload differences across the scenarios. Since performance did change, it would seem that workload should be varying as well. It is possible that the lack of significance is due to the fact that a low sample size was used for the workload measures. In addition, there is always room for inaccuracy when using subjective workload measures, and that could have been the case in this experiment.

11.6 In summary, the experiment appears to give some preliminary indication of the level at which performance declines using the ADS-B technology display.

ANNEX C. A – ACRONYMS AND ABBREVIATIONS

AAR	Airport Acceptance Rate
ADS-B	Automated Dependent Surveillance – Broadcast
ANOVA	Analysis of Variance
ATC	Air Traffic Control
CA	Closest Approach
CD	Conflict Detection
CDTI	Cockpit Display of Traffic Information
CI	Confidence Interval
CR	Conflict Resolution
CRE	Conflict Resolution Efficiency
CV	Conflict Volume
EARL	ERAU ATM Research Laboratories
ERAU	Embry-Riddle Aeronautical University
FAA	Federal Aviation Administration
HF	Human Factors
HSAC	Helicopter Safety Advisory Committee
HSD	Honestly Significant Difference
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
RI	Radar Inaccuracy
TRACON	Terminal Radar Approach Control
TV	Traffic Volume
VFR	Visual Flight Rules
TD	Traffic Density
TLS	Time to Loss of Separation
SDT	Signal Detection Theory

ANNEX C. B – REFERENCES

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