SEARCH PLANNING GUIDANCE FOR USE IN GENERAL AVIATION MISSING AIRCRAFT SEARCHES IN THE CONTINENTAL UNITED STATES

By

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The author would also like to thank the staff of that Air Force Rescue Coordination Center and the National SAR School as they provided a wealth of information and background that led to the overall success of this project.

Last, but definitely not least, I would like to thank my parents for always being there for me and pushing me towards being the best that I could be. The example that they set for me has shown me to work hard and always do what is right and will help others. I believe this project truly represents those values.

ABSTRACT

Writer: John William Desmarais

Title: Search Planning Guidance for use in General Aviation Missing Aircraft Searches in the Continental United States

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This project reviewed the latest information on general aviation missing aircraft searches in the Continental United States (CONUS) to provide search planners useful guidance for determining the optimal search area. Most planners have been utilizing the New Two-Area Method (NTAM) developed by the Canadian Department of National Defence's Directorate of Air Operational Research (DAOR). Though this method of planning has worked, it was never validated for use in the CONUS. The author recommends that planners adjust the second area of the NTAM to search a radius of 20 nautical miles or 20% of the original track length, which ever is greater, around the last known position, turning points along the route, and the destination as this yields better results.

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CHAPTER I

INTRODUCTION

General Background of the Study

Each year several thousand aviation searches are conducted in the Continental United States (CONUS) under the control of the Air Force Rescue Coordination Center (AFRCC). Most of these searches are for Emergency Locator Transmitters (ELT) that end up being false alarms, but a small percentage of these searches are for general aviation aircraft that are actually missing. Search planners, however, do not have the luxury of knowing if the search is a false alarm or not, and must do everything that they can to prosecute the searches assigned to them efficiently and safely with the hopes of a positive outcome. These missing aircraft searches are very intensive and tie up many resources that could be used elsewhere. Anything that can be done to lessen the burden on those involved will be appreciated.

Purpose of the Study

The United States Air Force is responsible for all federal Search-And-Rescue (SAR) conducted in the inland region of the United States and the AFRCC, currently located at Langley AFB, VA, is tasked with implementing the National SAR Plan to complete these searches (Joint Publication 3-50, 1991, p. 1-4) in the CONUS. Though there are discussions of a combined or joint rescue coordination center be established for the CONUS for maritime and inland SAR, the current draft of the revised National SAR Manual, Joint Publication 3-50, reflects the same responsibilities for the AFRCC. (Draft

Joint Publication 3-50, March 2000, p. 1-4) The AFRCC does not truly have any operational assets to conduct searches and must rely on other organizations to do that, though it provides as much planning support as is reasonably possible when not on-scene. Civil Air Patrol, the Congressionally chartered Auxiliary of the United States Air Force, conducts most of the missing aircraft searches in the field for the AFRCC. The author has a vested interest in making sure that CAP has the best tools and guidance possible on these searches as he is now responsible for the development of training curricula for emergency services personnel throughout the organization.

Current Methods

Currently, search planners are predominantly using the New Two-Area Method (NTAM) to layout how searches will be planned in the United States mainly because there is nothing else available. As outlined in the National SAR School's Inland SAR Planning Course Notebook (1996), The NTAM was developed by the Canadian Department of National Defence's Directorate of Air Operational Research (DAOR). The NTAM is based on research of seventy-six missing aircraft missions conducted in Canada from 1981 to 1986. To use the NTAM requires search planners to have the Last Known Position (LKP) of the missing aircraft (which is typically the origin of the flight), the intended route of the missing aircraft, and the intended destination of the missing aircraft. From this information two areas are defined for prioritizing the search.

Area One

To establish area one, the search planner draws a rectangle 10 nautical miles each side of the track of the missing aircraft beginning 10 nautical miles before the LKP of the missing aircraft and extending 10 nautical miles beyond the destination of the missing aircraft (National SAR School, 1996). This is depicted in figure 1 below.

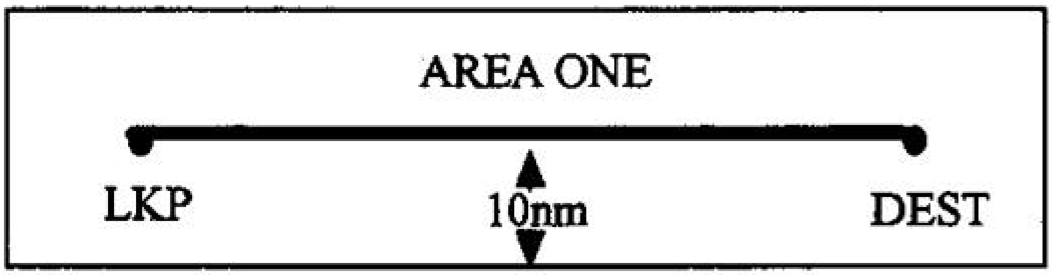

Figure 1. Area one of the NTAM as depicted in the National SAR School's Inland SAR Planning Course Notebook (1996).

Area Two

To establish area two, a rectangle is drawn 15 nautical miles along each side of the missing aircraft's track beginning at the LKP and extending 15 nautical miles beyond the destination; area two does include the portion of area one where this is overlap (National SAR School, 1996). Area two is depicted below in figure 2.

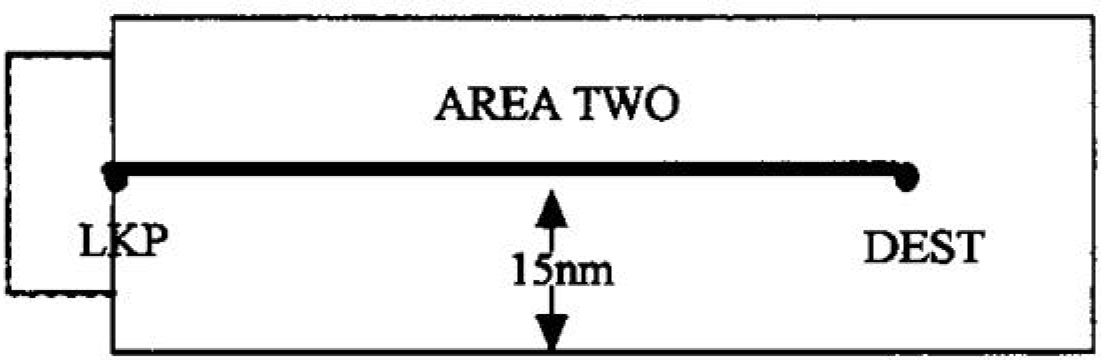

Figure 2. Area two of the NTAM as depicted in the National SAR School's Inland SAR Planning Course Notebook (1996).

En Route Turning Points

There are often known turning points along the intended route of flight that must be addressed in planning the search. Using the NTAM, this is addressed by drawing an arc using the turning point as the center with the radius equal to 10 nautical miles for area one and 15 nautical miles for area two (National SAR School, 1996). This is depicted in figure 3 below.

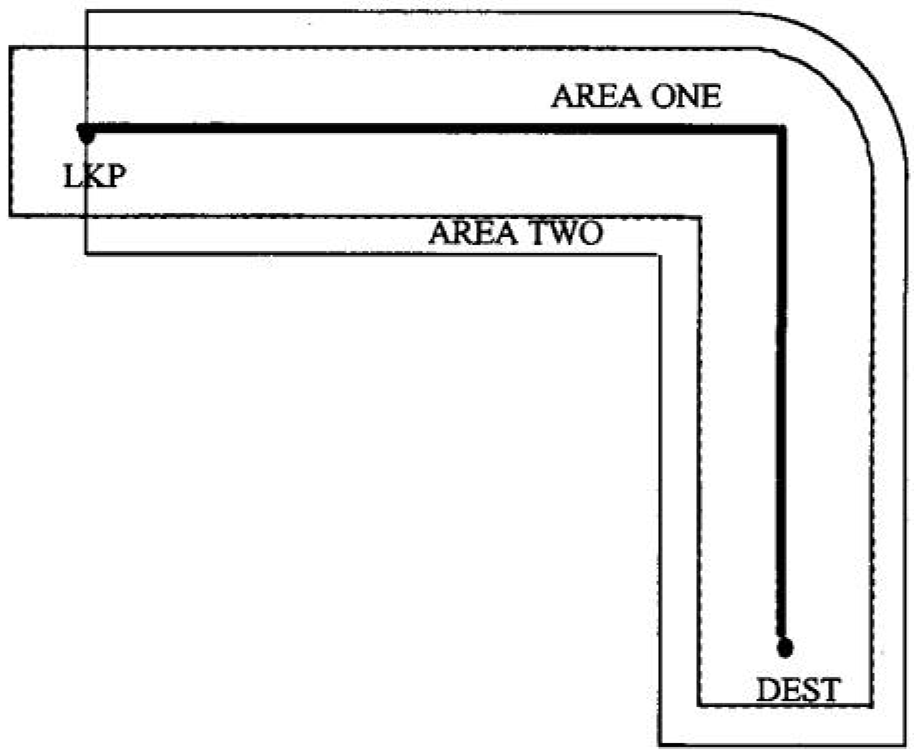

Figure 3. An example of a turning point using the NTAM as depicted in the National SAR School's Inland SAR Planning Course Notebook (1996).

Recommended Search Sequence

When utilizing the NTAM, the National SAR School recommends that searches be conducted in the following order unless the circumstances dictate otherwise (National SAR School, 1996):

First, conduct track crawls along the missing aircraft's intended tack, being especially thorough in the vicinity of the LKP and destination. Second, conduct electronic searches and cooperating target/survivor searches, covering the entire high probability areas. Third, search area one in the following order:

a. the last quarter of the track from the track outward with equal priority along the track;

b. the third quarter from the track outward with equal priority along the track;

c. the first quarter of the track outwards commencing at the LKP;

d. the second quarter from the track outward with equal priority along the track;

e. the over-fly area followed by the under-fly area commencing at the destination and LKP respectively.

Fourth, search area two using the same sequence established for searching area one. (p. 7-29)

The above search precedence was established because most of the missing aircraft were located close to the intended track. Additionally, there were high concentrations of aircraft found in the first and last tenth of the track, and more found in the second half of the track than the first (National SAR School, 1996). There was no firm criteria established for when to expand the search areas to include area two, though if planners are prudently using available resources this would not be accomplished until area one is completely or nearly completely searched.

NTAM Results

Utilizing the missing aircraft data from the 76 missions included in the DAOR study conducted from 1981 through 1986, the Canadians found that 79% of the missing aircraft were located in area one. After further research, the Canadians found that 83% of the missing aircraft were located in area two.

Up to this point, no research has been conducted in the United States to determine if similar results should be expected or if a different method should be utilized.

Problem Statement

Knowing the basic planning guidance currently in place, it is now time for the author to formally list the problem to be explored by this study. The problem to be investigated in this study is "Should the Canadian NTAM be utilized by search planners in the CONUS or not, and if not, what better alternatives are readily available?" There are many possible criteria for deciding whether to stick with the Canadian NTAM for searches conducted in the CONUS or not, and expertise will always guide the selection of alternative methods. The author's ideas on this subject are further defined in the following sections.

Guiding Questions

The first question that must be answered is "How many missing aircraft searches were coordinated in 1999 by the AFRCC, and what information is available for each search?" To reasonably review the data available for validity using the NTAM, the LKP, intended route, and intended destination of the missing aircraft must be known.
The author reviewed the mission folders kept on file at the AFRCC for the missing aircraft missions conducted in 1999, and found a sufficient number of missions and enough information available to conduct the research. (AFRCC Mission Records, 1999)

It may be necessary to query the NTSB online database of aircraft accidents and incidents to get more data for some of the missions, but this should not be a problem. (NTSB, 2000) One hundred and fifteen missing aircraft searches of varying types were conducted in 1999. Some of these searches were initiated based on FAA Alert Notices (ALNOTs), some on reports from family or friends that the aircraft was overdue, others based on loss of radar contact, and still others because of known distress signals from Emergency Locator Transmitters (ELT) or mayday calls. With more detailed review of the above missions the author eliminated 37 missions from the study, but there were still enough remaining to reasonably compare the results to the Canadian studies conducted to develop the NTAM. The reasons for eliminating missions from study can be found in the additional questions to be answered.

The second question that has been answered is "What relevant information is normally available to mission planners that could further impact planning efforts?" Search planners must know the LKP, route, and destination as previously discussed, but there are other mitigating factors that often allow planners to focus the search efforts. Things that could focus search efforts would be things like a known flight plan, reports from concerned family or friends, radar, National Track Analysis Program (NTAP) data, or known ELT signals or distress calls in the area of possibility of the search. In fact AFRCC controllers are told in their training to learn how to prosecute missing aircraft missions that "NTAP data, when available, is possibly the best tool available to limit the search area for a missing aircraft." (AFRCC Controller Training, 1999) This type of information directs planners to focus search efforts in one area and avoid others. The only problem is that the data available is not the same for every search. Though research shows that filing a flight plan significantly reduces the time until SAR resources are dispatched, pilots even on long cross countries still fail to file a flight plan. (Homes, July 1999, p. 2) And even though ELTs are required to be carried on board all civil aircraft in the United States according to the Federal Aviation Regulation, part 91, they do not always work since they are often destroyed in a crash. (FAA, 2000)

The third question to be answered was "Where were the missing aircraft actually located?" If the aircraft involved in the search was never located, it is not useful to this research. Also, not all missing aircraft will be found having crashed, as evidenced by the many incidents and false search missions conducted for people who simply forgot to close out their flight plan and whose planes were located at an airport by a ramp check. The only problem is that search planners do not know if an aircraft is truly missing or if the mission is a false alarm until the aircraft is found. Therefore, for the purposes of this study, these missions were left in the study.

Fourth, "Will changes to structure of the areas to be searched in CONUS yield better results than if search planners continued to use the NTAM?" The author compared the results using the NTAM with alternative designs. The author used his own background as a search planner and incident commander and his access to others with like qualifications to develop an alternative design that search planners might utilize.

Finally, "Does the available information justify search planners changing their current methods?" Time is very limited in planning searches, and anything that can be done to speed up the process is normally appreciated by all involved. The author was careful to avoid making additional unnecessary work for search planners in any recommendations that he has made, and to try to make those same recommendations simple for search planners to implement in the field.

Significance of Study

The goal of this study was to determine the validity of using NTAM in the CONUS for conducting missing aircraft searches and to recommend changes for search planners if necessary. What makes this significant? A new method of conducting searches could reduce the time it takes to find survivors of plane crashes, and thus save lives. Additionally, even if the NTAM were determined to be the best method of conducting missing aircraft searches in the CONUS, search planners will now know this and have the data to review on hand. Every organization involved in saving lives should be looking at the legal ramifications of how their personnel conduct searches, and if their planners do not use the most efficient methods to find missing aircraft, eventually the organization will be sued and the results may not be favorable. This research gives search planners a defensible position from which to work.

CHAPTER II

REVIEW OF LITERATURE

There is very little information available on the subject of missing aircraft search in the continental United States, or anywhere else in the world for that matter. The organizations that are primarily responsible for conducting the searches for missing aircraft in the United States, the AFRCC and CAP, have been utilizing the only documented tool available to them, the NTAM. This is not written to place blame or fault on anyone, but because of budget and personnel constraints, nothing has been done to expand upon the research conducted by the DAOR for the searches conducted in the CONUS.

Regulatory Guidance in the United States

Search planning for missing aircraft searches in the United States is guided mainly by Joint Publication 3-50, The National Search And Rescue Manual. This publication, though valuable, does very little to support the planning requirements for missing aircraft searches. A large portion of the manual is devoted to maritime search, and also has guidance and responsibilities for the staff at all levels in the organizational structure of a search. Though this document provides valuable background information that can be useful to those coordinating a search, it does very little to establish guidance for true search planning for missing aircraft.

Pilots in the United States operate under Title 14 of the Code of Federal Regulations, the Federal Aviation Regulations when operating their aircraft. The Federal

Aviation Regulations in conjunction with the Airmen's Information Manual do provide survival tips and guidance for pilots after having crashed their aircraft that can help them to be located sooner by searchers. It does not however provide guidance for the search planners as to where to search.

The primary organization responsible for actually conducting searches for missing aircraft in the United States, CAP, provides regulatory guidance to it's emergency services personnel mainly in the areas of operating limitations and structure in CAP Regulations 55-1 and 60-1. These regulations also do not have any specific policies for where to begin a search. It is left up to the individual staff of the mission in conjunction with the coordinating agency, normally the AFRCC, to establish the best plan to resolve the issue. This planning normally ends up following the guidance established by the National SAR School as this school trains the majority of executive level search planners in CAP and the USAF.

National SAR School Materials

The National SAR School, located at the Coast Guard Reserve Training Center in Yorktown, Virginia, utilizes the most up to date materials available to train their students. Each student receives the Inland SAR Planning Course Notebook, which is updated with the most current information on a variety of topics ranging from legal aspects in SAR to the strategy and tactics required for missing aircraft searches. There are many emerging issues in SAR addressed at the school, and only so much time can be spent on research by the few staff members assigned at the school. The current Inland SAR Planning Course Notebook recommends the NTAM and provides background on how the NTAM was developed. The NTAM is a variant of the Offset and Track Variable (OTV) and

Modified Offset and Track Variable (MOTV) methods developed by the Canadian Department of National Defence in the 1970s and early 1980s. The NTAM is based on statistical information from 76 searches conducted in Canada in the early 1980s, and is accepted by search planners as the most reasonable approach available presently. Most of the information from the Inland SAR Planning Course Notebook on the subject is from notes and memos from the DAOR in Canada, which at present will not be released for public use outside of the DAOR.

CHAPTER III

METHODOLOGY

Subjects

The sample constitutes the 78 missing aircraft search missions of varying types coordinated by the AFRCC in 1999 that are valid for the study.   These 78 missions represent approximately three percent of the 2,719 missions coordinated by the AFRCC in 1999. From discussion with the staff of the AFRCC this seemed reasonable as they would normally expect between 60 and 100 missing aircraft missions of varying types throughout any given year (C. D. Holmes, personal communication, January 12, 2000). As previously stated, there were actually 115 missing aircraft searches conducted in CONUS in 1999, but 37 of the searches did not meet the criteria for the study. It should also be noted that the AFRCC is only responsible for searches conducted in the CONUS, and the research conducted does not include searches conducted outside of the CONUS.

Instrument

To gather the required data for this project, the author used a simple database to gather the known crash site location, LKP, turning points, destination, and mitigating factors that might influence a search planner's decision like known radar plots or ELT signals. As the author reviewed the available information in more depth, greater expansion of this database was warranted to give more detailed explanations to the end-users of this research project.

Research Design

This study was primarily a statistical analysis. The author determined if it is reasonable for search planners in the CONUS to use the NTAM or if they should use some other method. This was based on data collected from the AFRCC mission folders for all missing aircraft missions of varying types conducted in 1999 as well as the NTSB Aviation Accident/Incident Database. Using the factual records of the missing aircraft missions conducted in 1999, the author first determined the percentage of missing aircraft that were found in area one of the NTAM, then area two of the NTAM, and then those found outside of the areas established by the NTAM. The author then reviewed the locations of the missing aircraft to determine if there might be a better search formula to be utilized in the CONUS and compare the results.

Procedures

First, the author collected the required information to validate the NTAM as established in the above instrument section of this chapter. This data was made readily available to the author by the AFRCC staff who were very interested in the results of this research, and the NTSB database was fairly simple to query online.

Second, the author determined how far off of the search track each aircraft was for the statistical analysis. To do so, the author used a computer software program utilized by search planners, SAR Viewpoint Version 2.1. This program has many utilities that allowed the author to plot the tracks of the missing aircraft as well as readily determine the distance from the track the missing aircraft was located at in nautical miles.

Third, the author determined the number of missing aircraft located in CONUS that were in area one using the NTAM.

Fourth, the author determined the number of missing aircraft located in CONUS that were within area two using the NTAM.

Fifth, the author determined the number of missing aircraft located in CONUS that were not within either area one or area two of the NTAM.

Sixth, based on the available information, the author determined that there are other reasonable areas that search planners could implement that might yield better results than the NTAM in the CONUS.

Finally, the author has recommended a method for search planners to effectively prosecute missing aircraft search missions within the CONUS. This not only took into account the simple distances off of track of the missing aircraft, but also other mitigating factors like known ELT or other distress signals, radar plots, or reports from witness or family members.

CHAPTER IV

RESULTS

In following the procedures established in the previous chapter the author documented the following results.

General Results

The author found the mean distance off of track for aircraft in the study to be 12.74 nautical miles. The author also found that mean distance that the aircraft in the study were found along the track was 64% of the intended track length. This can be further refined when not taking into account false missions. After removing false missions the mean distance off of track was 15.57 nautical miles while the mean distance that the aircraft were found along the track was 57% of the intended track length. A detailed table outlining the distances along and from the track by mission number can be found in Appendix A.

Results of Using the NTAM Area One

The author also found that 55 of the 78 aircraft in the study were located in area one using the NTAM. This is approximately 71% of the aircraft involved in the study. If the data is again refined to exclude false missions, 40 of the 62 aircraft were located in area one using the NTAM, approximately 65% of the aircraft located on actual missions. A detailed table listing the missions that the aircraft were located in area one of the NTAM can be found in Appendix B.

Results of Using the NTAM Area Two

The author determined that 59 of the 78 aircraft in the study were located in area two using the NTAM. This is approximately 76% of the aircraft involved in the study. After refining this data further to eliminate false missions, 43 of the 62 aircraft were located in area two using the NTAM, approximately 69% of the aircraft located on actual missions. A detailed table listing the missions that the aircraft were located in area two of the NTAM can be found in Appendix C.

Negative Results Using the NTAM

After determining the aircraft located in area one or two of the NTAM, the author calculated that 19 of the 78 aircraft in the study were not located in area one or area two using the NTAM. This is approximately 24% of the aircraft involved in the study. After removing false missions, 19 of the 62 aircraft located on actual missions were found outside of area one or two using the NTAM which is approximately 31% of the aircraft located on actual missions.

Results of Using an Alternative to the NTAM

After reviewing the results of implementing the Canadian NTAM, the author decided to try an alternative method to make a reasonable comparison. The author took a two staged approach as well. The first stage is the same as the NTAM, and the reader obviously already knows the results of that comparison. For the second stage of searching the author chose to have searches conducted within a radius of 20 nautical miles or 20% of the track length, whichever is greater, around each turning point along the route, the destination, and the LKP. Diagrams showing this revised second area are depicted in Figures 4 and 5. This resulted in 66 of the 78 aircraft in the study being located, which is approximately 85% of the aircraft involved in the study. After eliminating the false missions, 51 of the 62 aircraft remaining were found in this area, which represent approximately 82% of the actual missing aircraft involved in the study. A table documenting the results of using this revised second area by mission can be found in Appendix D.

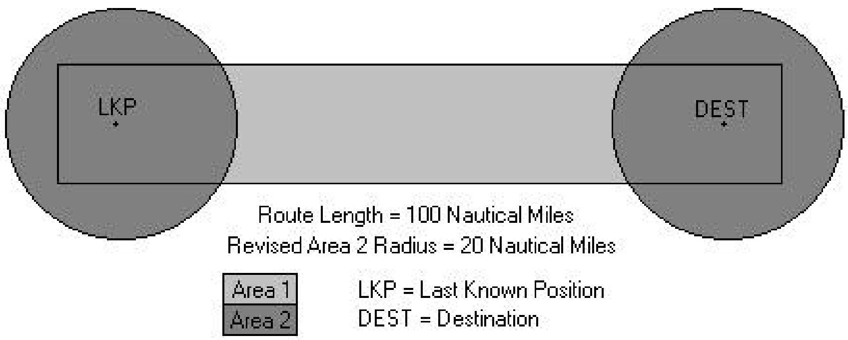

Figure 4. Revised Second Area Example One.

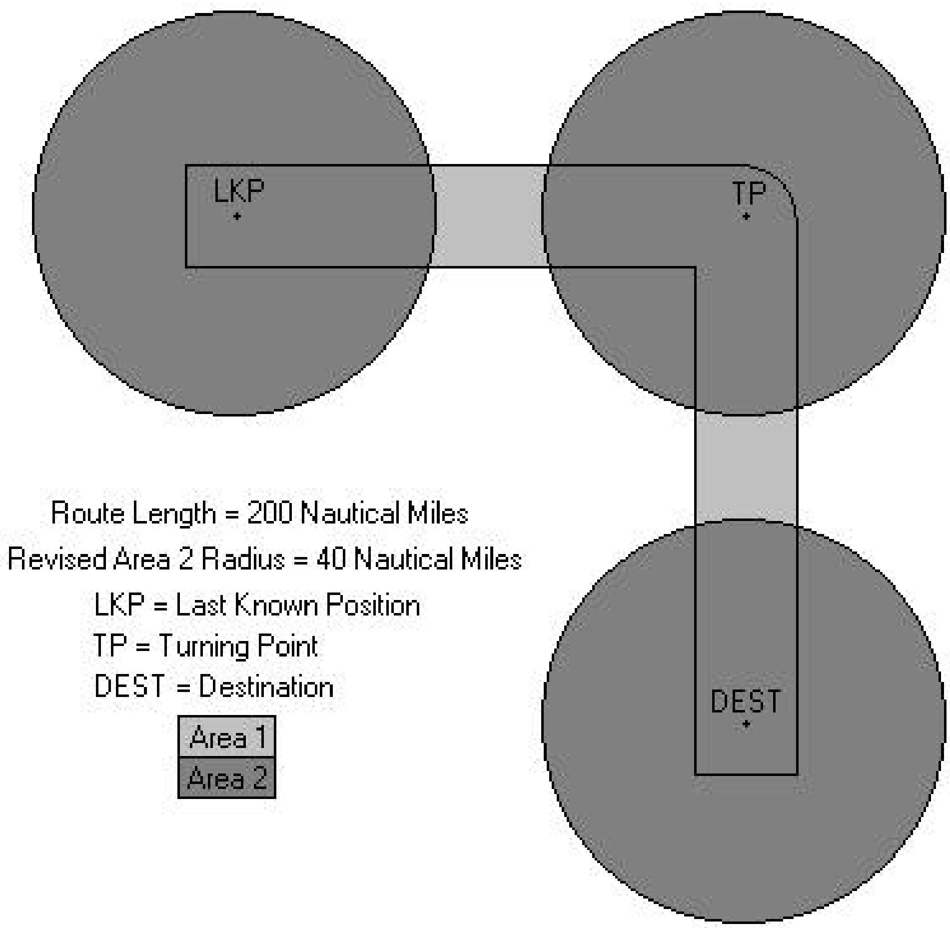

Figure 5. Revised Second Area Example Two

CHAPTER V

DISCUSSION

The results presented in the previous chapter speak for themselves on several issues, but do not clarify the research for the reader. There are several issues that readers need to be aware of as they review this research project that the author will go into more depth about in the following sections.

Limited Available Information

Though the author was able to collect enough information to conduct his research, he sometimes had a very difficult time doing so. This is not being mentioned to place blame on any organization or individuals, but does need to be brought up. Search planners are often faced with extremely limited information to work with, and that can often only be blamed on the missing pilot. Flight plans provide some useful information on where to start, but are often not detailed enough to properly limit a search area, and that assumes that the pilot even filed a flight plan. Many searches were initiated based on reports from family members or the owner of the aircraft, and often had even less information than is normally provided on a flight plan. It was blatantly obvious to the author in reviewing the data available to search planners that pilots do not expect to have an accident, and thus cut corners when providing information that could be helpful to searchers who are tasked to find them when they are lost. Several searches did not start until days after the pilot's accident because nobody noticed the aircraft and crew were overdue or missing. Additionally, even if there was data available the search planners are forced to investigate many leads to limit the search area in the hopes of locating survivors. It is not often easy to determine if an aircraft made it to one or more of its destinations, especially if the pilot only over-flew a field, and did not land or communicate with people at that point along the route of flight. This problem is further exacerbated when definitive data from radar or NTAP may not be available or when it is it could be days before it can be processed and made available to planners. Pilots need to understand that just because you are using a transponder with a squawk code that does not mean that someone is listening or will have an exact location on you right away. The pilot and crew need to do everything that they can to help searchers should they get into trouble, and much of that can be done before they ever get into the airplane.

False verses Actual Missions

Search planners do not know if an aircraft has had an accident or has landed safely when initiating their efforts. Of the 78 missing aircraft search missions conducted in the CONUS in 1999 that were included in this project study, 16 were false alarms, or approximately 21% of the missions included in the study. In 15 of the 16 cases the aircraft was located safe on the ground somewhere along the route, and in one case an aircraft was located safe at an airport not along the route. All of these aircraft were located by searchers conducting ramp checks, and in every case the pilot had simply failed to close his or her flight plan. This is a waste of valuable resources and also forces search planners to consider this option in assigning tasks to search personnel. Many personnel conducting ramp checks could be used to search other areas of high probability on actual missions, but cannot be because they must eliminate the possibility of a false alarm.

Distance Along the Track

As noted in the previous chapter, the mean distance along the track that actual missing aircraft were located was 57% of the track length. Search planners need to have this broken down further to better understand how to focus search efforts. Table 5 below shows how many aircraft were located in 10% increments of the track length. Aircraft located before the LKP or after the destination are grouped into their own categories in the table.

Table 5

Crash Location Segment Breakdown

Distance Along Track Location	Number of Aircraft Located in Section	Percentage of Aircraft Located in Section
Before the LKP	4	6.45
LKP to 10% of Track	10	16.13
10% to 20% of Track	4	6.45
20% to 30 % of Track	5	8.06
30% to 40% of Track	4	6.45
40% to 50% of Track	1	1.61
50% to 60% of Track	3	4.84
60% to 70% of Track	2	3.23
70% to 80% of Track	1	1.61
80% to 90% of Track	5	8.06
90% of Track to Destination	12	19.35
After the Destination	11	17.74
Total Number of Actual Searches	62	

Note. This data represents the locations of actual missing aircraft within the study based on the original track, and does not include false missions.

Intended Track Length

The intended track lengths for each of the searches included in the research study varied greatly. The shortest track length was 7.53 nautical miles while the longest was

1,231.40 nautical miles. In all cases the LKP was also the origin for the flight. This is typical for the initial search planning efforts, but can make the search area much larger than it should be. The author found in his study that as additional leads were tracked down and more information made available, search planners were able to adjust the LKP and significantly decrease the size of the search area. Several of the missing aircraft were located very close to their adjusted LKP. Table 6 indicating the distanced from the adjusted LKP that the missing aircraft were located is included in Appendix E. The mean distance that missing aircraft were found from an updated LKP for actual missions was 24.72 nautical miles, with the shortest distance being right on top of the adjusted LKP to the greatest distance being 141.6 nautical miles from the updated LKP. As several of the aircraft were located at or extremely close to the updated LKP, planner should conduct hasty searches around updated LKPs as soon as possible.

NTAM Results

The results of using the Canadian NTAM were no where near as good in the CONUS as they were in Canada. For actual missions area one of the NTAM yielded a 65% found in the CONUS in comparison to the 79% found in Canada. For actual missions area two of the NTAM yielded a 69% found in the CONUS in comparison to the 83% found in Canada. In both situations this is much lower than search planner would find acceptable. This suggested to the author that there had to be a better way. A "D" is never really acceptable in any school, and this is what the Canadian NTAM was advocating for use in the CONUS. If search planners will be expected to defend their position to their peers, or possibly in court to a jury, then the method implemented in the CONUS needs to yield the same or better results than the Canadian NTAM.

Alternatives to the Canadian NTAM

There are several possible alternatives to the using the Canadian NTAM, but each has its own drawbacks. The author tried to minimize additional workload on search teams, planners, managers and searchers alike, while maximizing the number of aircraft located in the search area.

In deciding on a logical alternative the author chose to leave first area searched the same as the Canadian NTAM. This was done for two main reasons. First, many of the aircraft located in the study were found within this window, both actual and false. Second, as information is normally extremely limited at the beginning of a search, route searches along the only area of known probability, the intended route of the aircraft, is really the only alternative to waiting for more information. As it is considered better for these assets to be doing something rather than sitting idle waiting for better leads, route searches seem reasonable. Area one of the NTAM was considered acceptable by search planners. Searching an area any larger than this in the first stage was determined to be a poor decision unless it could be strongly defended.

In considering the established limitations of the search area for the first stage of the search, the author decided to look at better alternatives for area two. The only way to yield significantly better results than by using the Canadian NTAM was to either greatly increase the overall track to be searched or to search higher probability areas. Past education in crash investigation reminded the author that most aircraft accidents occur in the early or late stages of flight, and thus he decided to see if it was better to focus the second stage of the search expansion on the LKP, destination, and known turning points along the route. The author reviewed several alternatives for the second stage search.

In trying to keep the math simple for search planners, the author first review expanding the search area to 20 nautical miles around the LKP, destination and known turning points. This yielded a find rate of approximately 73% found on actual missions which is better than using the Canadian NTAM that yielded a 69% rate. The author's first choice already resulted in a better conclusion, which guided him to trying other alternatives.

First he tried establishing the second search area as a radius of 10% of the intended track length around the LKP, turning points and the intended destination. This yielded a rate of approximately 68% found on actual missions, which compared to the Canadian NTAM results was worse, but not significantly.

Then the author tried expanding the second search area to a radius of 20% of the intended track length around the LKP, turning points and the intended destination. This resulted in approximately 77% percent of the actual missing aircraft being located in that search area, which is significantly better than if using the Canadian NTAM, and also yielded better results than using the author's first alternative of a 20 nautical mile radius.

Finally, the author decided to combine his two best alternatives to see if that yielded any better results. By making the second area 20 nautical miles or 20% of the intended track length, whichever was greater, the author found that approximately 82% of the missing aircraft would have been located. This was the best alternative, and also better than using the Canadian NTAM, which is why it was chosen as the alternative example. It should also be noted that this data is based on using the original LKP for determining track length, not updated or adjusted LKPs as this could significantly reduce the area searched around the LKP, turning points, and final destination. The author did this for two reasons. First, he noted a tendency for aircraft on longer routes tending to be farther away from the intended track, justifying a larger area being searched. Second, planners are often staging crews at several different location often great distances apart, and this allows planning to take a more forward leaning approach. More search assets may be pre-positioned in certain sections of the search area, and thus could expand into searching area two before other locations are ready to do so. It could be advantageous to move search assets to provide better coverage of the search area, but this may not be possible for a number of reasons like weather restrictions, search crew availability, or other aircraft operations or maintenance limitations.

CHAPTER VI

CONCLUSION

The Canadian NTAM, though appropriate to use when search planners have nothing else to go on, is not the best method for planning missing aircraft searches in the CONUS. The author's research indicates that alternative methods to the NTAM would yield much better results in the CONUS. Search planners should use alternative methods to the Canadian NTAM. The author will give recommended search strategy for missing aircraft searches conducted in the CONUS in chapter seven of this project.

CHAPTER VII

RECOMMENDATIONS

The author has several recommendations from conducting this research.

Search Planners

The author would like to make the following recommendation to search planners in the CONUS:

First, as early as possible in the search conduct ramp searches of the airports along the intended route of flight, especially the intended destination so as to eliminate those airports for false missions. This is a good job for the first arriving crews to perform while a more specific search area is being delineated and more resources become available. Often these resources will be en route from locations near or even co-located with the LKP, turning points along the route, or the final destination of the missing aircraft, and it is easier for them to start searching from there rather than have to turn back unnecessarily.

Second, assuming that you have no other available information other than the intended route of flight, establish your first area to be searched the same as the Canadian NTAM: a rectangular search area 10 nautical miles either side of the intended route extended 10 nautical miles beyond the intended destination and 10 nautical miles before the LKP. It is further recommended that you search that route with the following precedence:

1. The last 20% of the route, from the destination backwards searching from the track outwards with equal priority along the track;

2. The area immediately surrounding the destination after the last 10% of the route searching from the track outwards with equal priority;

3. The first 20% of the route, from the LKP forwards searching from the track outwards with equal priority along the track;

4. The area immediately surrounding the LKP before the first 10% of the route searching from the track outwards with equal priority along the track;

5. Search the remaining portions along the route from the LKP to the destination searching from the track outwards with equal priority along the track;

Note that if there is a more accurate updated LKP than the origin of the flight like NTAP data or known sightings then the area immediately surrounding the updated LKP outwards to 10 nautical miles with equal priority should be searched prior to initiating the above search sequence. If this updated LKP suggests it, eliminate areas that are no longer necessary to search.

Third, after completing a thorough search of area one, initiate a second stage search. This search expands upon the first search area to search in more detail around the LKP, turning points along the route and the destination. The second stage area of this new method expands the search area to a 20 nautical mile or 20% of the original track length, whichever is greater, radius around the original LKP, turning points, and destination. Areas of overlap with area one should be searched again as those tend to be the highest areas of probability. It is further recommended that you search this area with the following precedence:

1. The area immediately surrounding the final destination from the final destination outwards with equal priority;

2. Turning points within the last 20 percent of the original track length from the turning point outwards with equal priority;

3. The area immediately surrounding the original or updated LKP searching from outwards with equal priority;

4. Search the remaining turning points along the route from the original or updated LKP to the destination searching from each turning point outwards with equal priority;

Note that if there is a more accurate updated LKP than the origin of the flight like NTAP data or known sightings then the area immediately surrounding the updated LKP outwards to 20 nautical miles or 20% of the original track length, whichever is greater, should be searched with equal priority prior to initiating the above search sequence. If this updated LKP suggests it, eliminate areas that are no longer necessary to search.

Fourth, plan for expansion and the need for additional resources. If ramp searches and searches of the high priority areas are not successful, then a full blown search using the method recommended above is definitely required, and that will most likely be resource intensive.

Fifth, early on, set reasonable objectives for your personnel including when you plan to close or suspend your search efforts. At some point in time all leads will be exhausted, the reasonable possibility that survivors will be found does not exist, or the risk to searchers will be too great to warrant a continued search. Set reasonable limits to avoid looking for one of your own crews that exceeded their limitations.

Management and Instructors

Those responsible for managing search agencies and those teaching search managers and planners need to stay abreast of the issues involved in this study. Part of the reason that this study was conducted was because there had never been an effort in the CONUS to determine if use of the NTAM was appropriate. It was also conducted because even if it had been validated informally by search managers agreeing with the conclusions of the Canadian NTAM, nobody had truly reviewed the data recently. As technology changes rapidly, so could the areas to be searched and the guidance to search managers and planners.

For Any Reader

By reviewing the results of this study you have shown that you obviously have an interest in the subject matter for one reason or another. Consider expanding upon this study at a later date and expanding upon my work. Also consider validating or invalidating my work. There could be many changes between when I wrote this project report and when you do another study. You might find very similar or dissimilar results. Either way, your help and guidance could save lives, and these things we do so that others may live.

REFERENCES

Air Force Rescue Coordination Center. (1999). AFRCC Basic Controller Inland SAR Training and Certification, Lesson 6E. Langley Air Force Base, VA: U.S. Air Force.

Air Force Rescue Coordination Center. (1999). Mission Records and Folders. Langley Air Force Base, VA: U.S. Air Force.

Federal Aviation Administration. (2000). Federal Aviation Regulations, Part 91. Washington, DC: Federal Aviation Administration.

Holmes, Christopher D. (July 1999). Where to Look: How VFR Flight Plans Affect a Search and Rescue Response. Unpublished graduate research project, Embry-Riddle Aeronautical University Extended Campus, Langley Air Force Base, VA.

National SAR School. (1996). Inland SAR Planning Course Notebook. Yorktown, VA: U.S. Air Force.

National Transportation Safety Board. (2000). NTSB Aviation Accident/Incident Database. Washington, DC.

U.S. Department of Defense. (1991). National Search And Rescue Manual (Joint Publication 3-50). Washington, DC: Joint Chiefs of Staff.

U.S. Department of Defense. (March 2000). Draft National Search And Rescue Manual (Joint Publication 3-50). Washington, DC: Joint Chiefs of Staff.

APPENDIX A

TABLE 1

Table 1

Detailed Table of Missions

Mission Number	Track Length (NM)	Distance Along Track (NM)	Distance Along Track (%)	Distance From Track (NM)
99M0011A	61.82	48.83	79	4.10
99M0046A	166.60	49.70	30	7.11
99M0076	27.27	27.45	101	0.45
99M0106	244.10	142.20	58	24.30
99M0123A	51.48	44.44	86	1.96
99M0140A	204.90	198.53	97	8.12
99M0162	342.90	342.77	100	0.27
99M0187A	251.20	52.10	21	51.10
99M0198A	273.30	272.98	100	8.51
99M0244A	121.50	111.10	91	20.80
99M0261	445.30	0.66	0	0.25
99M0308A	270.46	(16.90)	(6)	103.90
99M0342A	326.20	129.80	40	32.50
99M0392	280.70	(0.65)	(0)	0.53
99M0427A*	519.00	519.00	100	0.00
99M0491A	8.52	8.55	100	0.30
99M0540A	120.80	47.90	40	4.17
99M0604	709.72	47.10	7	9.66
99M0657A	269.95	275.02	102	5.18
99M0729A	246.00	72.30	29	7.36
99M0794A	662.02	0.65	0	2.66
99M0851	180.00	118.80	66	3.46
99M0860A	191.20	175.50	92	0.49
99M0892	345.50	318.60	92	0.56
99M0904A	25.32	31.24	123	11.68
99M0908	57.47	0.80	1	1.02
99M0920A*	50.00	50.00	100	0.00
99M1013A*	103.20	98.66	96	28.20
99M1090A*	151.85	151.85	100	0.00
99M1119*	532.00	532.00	100	0.00
99M1152A	560.60	527.00	94	0.24
99M1179*	174.12	149.32	86	0.00
99M1180	164.60	137.50	84	28.20
99M1192	74.28	22.10	30	0.30
99M1202A	63.94	31.97	50	0.50
99M1231A	139.00	(0.26)	(0)	10.20
99M1313A	130.10	129.92	100	0.17
99M1448A	159.00	107.80	68	9.22
99M1470A	101.80	101.92	100	0.12
99M1476	329.00	338.38	103	13.99

99M1510	169.10	151.50	90	3.08
99M1539A	524.40	492.80	94	7.87
99M1566*	256.50	256.50	100	0.00
99M1603A	76.14	69.61	91	7.42
99M1614	296.50	48.30	16	17.50
99M1635*	578.60	374.59	65	0.16
99M1652*	333.20	333.20	100	0.00
99M1692	1130.90	556.70	49	21.20
99M1708A	325.90	326.19	100	0.24
99M1718A	333.32	0.45	0	0.48
99M1726A	153.80	228.60	149	145.80
99M1764	320.20	5.16	2	3.89
99M1860A	133.00	121.00	91	7.77
99M1880A*	222.81	222.81	100	0.00
99M1910A	546.00	477.50	87	36.40
99M1923	65.27	63.20	97	10.40
99M1939	340.20	286.90	84	59.80
99M2085	1231.40	160.80	13	19.20
99M2209	461.36	4.88	1	0.31
99M2210	60.16	1.95	3	1.92
99M2280A*	54.15	54.15	100	0.00
99M2282	108.10	25.90	24	2.95
99M2292	26.49	1.65	6	1.44
99M2322	371.20	139.90	38	20.10
99M2360	105.17	(86.30)	(82)	91.73
99M2373A*	60.26	60.26	100	0.00
99M2387*	105.40	105.40	100	0.00
99M2464*	59.65	59.65	100	0.00
99M2481	7.53	13.73	182	10.39
99M2509A*	373.22	373.22	100	0.00
99M2541*	54.19	0.00	0	0.00
99M2574	351.70	351.86	100	0.23
99M2611A	260.15	145.00	056	36.60
99M2621A	85.47	9.97	12	7.55
99M2636A	897.80	140.90	16	15.90
99M2684A	665.80	667.88	100	1.48
99M2703	325.90	125.40	38	43.90
99M2712	32.66	2.17	7	16.20
Total number of actual missions			62	
Total number of false missions			16	
Total number of missions			78	

Note 1. Negative numbers are shown in parentheses.
Note 2. False Missions are annotated with an asterisk (*)
Note 3. The above data was derived from the 1999 mission records of the AFRCC. (AFRCC Mission Records, 1999)

APPENDIX B

TABLE 2

Table 2

Missions having Aircraft Found in Area One using the NTAM

Mission Number	Track Length (NM)	Distance Along Track (NM)	Distance Along Track (%)	Distance From Track (NM)
99M0011A	61.82	48.83	79	4.10
99M0046A	166.60	49.70	30	7.11
99M0076	27.27	27.45	101	0.45
99M0123A	51.48	44.44	86	1.96
99M0140A	204.90	198.53	97	8.12
99M0162	342.90	342.77	100	0.27
99M0198A	273.30	272.98	100	8.51
99M0261	445.30	0.66	0	0.25
99M0392	280.70	(0.65)	0	0.53
99M0427A*	519.00	519.00	100	0.00
99M0491A	8.52	8.55	100	0.30
99M0540A	120.80	47.90	40	4.17
99M0604	709.72	47.10	7	9.66
99M0657A	269.95	275.02	102	5.18
99M0729A	246.00	72.30	29	7.36
99M0794A	662.02	0.65	0	2.66
99M0851	180.00	118.80	66	3.46
99M0860A	191.20	175.50	92	0.49
99M0892	345.50	318.60	92	0.56
99M0908	57.47	0.80	1	1.02
99M0920A*	50.00	50.00	100	0.00
99M1090A*	151.85	151.85	100	0.00
99M1119*	532.00	532.00	100	0.00
99M1152A	560.60	527.00	94	0.24
99M1179*	174.12	149.32	86	0.00
99M1192	74.28	22.10	30	0.30
99M1202A	63.94	31.97	50	0.50
99M1313A	130.10	129.92	100	0.17
99M1448A	159.00	107.80	68	9.22
99M1470A	101.80	101.92	100	0.12
99M1510	169.10	151.50	90	3.08
99M1539A	524.40	492.80	94	7.87
99M1566*	256.50	256.50	100	0.00
99M1603A	76.14	69.61	91	7.42
99M1635*	578.60	374.59	65	0.16
99M1652*	333.20	333.20	100	0.00
99M1708A	325.90	326.19	100	0.24
99M1718A	333.32	0.45	0	0.48
99M1764	320.20	5.16	2	3.89

99M1860A	133.00	121.00	91	7.77
99M1880A*	222.81	222.81	100	0.00
99M2209	461.36	4.88	1	0.31
99M2210	60.16	1.95	3	1.92
99M2280A*	54.15	54.15	100	0.00
99M2282	108.10	25.90	24	2.95
99M2292	26.49	1.65	6	1.44
99M2373A*	60.26	60.26	100	0.00
99M2387*	105.40	105.40	100	0.00
99M2464*	59.65	59.65	100	0.00
99M2509A*	373.22	373.22	100	0.00
99M2541*	54.19	0.00	0	0.00
99M2574	351.70	351.86	100	0.23
99M2621A	85.47	9.97	12	7.55
99M2684A	665.80	667.88	100	1.48
Total number of actual missions			39	
Total number of false missions			15	
Total number of missions			54	

Note 1. Negative numbers are shown in parentheses.
Note 2. False Missions are annotated with an asterisk (*)
Note 3. The above data was derived from the 1999 mission records of the AFRCC.
(AFRCC Mission Records, 1999)

APPENDIX C

TABLE 3

Table 3

<u>Missions having Aircraft found in Area Two using the NTAM</u>

Mission Number	Track Length (NM)	Distance Along Track (NM)	Distance Along Track (%)	Distance From Track (NM)
99M0011A	61.82	48.83	79	4.10
99M0046A	166.60	49.70	30	7.11
99M0076	27.27	27.45	101	0.45
99M0123A	51.48	44.44	86	1.96
99M0140A	204.90	198.53	97	8.12
99M0162	342.90	342.77	100	0.27
99M0198A	273.30	272.98	100	8.51
99M0261	445.30	0.66	0	0.25
99M0392	280.70	(0.65)	0	0.53
99M0427A*	519.00	519.00	100	0.00
99M0491A	8.52	8.55	100	0.30
99M0540A	120.80	47.90	40	4.17
99M0604	709.72	47.10	7	9.66
99M0657A	269.95	275.02	102	5.18
99M0729A	246.00	72.30	29	7.36
99M0794A	662.02	0.65	0	2.66
99M0851	180.00	118.80	66	3.46
99M0860A	191.20	175.50	92	0.49
99M0892	345.50	318.60	92	0.56
99M0904A	25.32	31.24	123	11.68
99M0908	57.47	0.80	1	1.02
99M0920A*	50.00	50.00	100	0.00
99M1090A*	151.85	151.85	100	0.00
99M1119*	532.00	532.00	100	0.00
99M1152A	560.60	527.00	94	0.24
99M1179*	174.12	149.32	86	0.00
99M1192	74.28	22.10	30	0.30
99M1202A	63.94	31.97	50	0.50
99M1231A	139.00	(0.26)	0	10.20
99M1313A	130.10	129.92	100	0.17
99M1448A	159.00	107.80	68	9.22
99M1470A	101.80	101.92	100	0.12
99M1476	329.00	338.38	103	13.99
99M1510	169.10	151.50	90	3.08
99M1539A	524.40	492.80	94	7.87
99M1566*	256.50	256.50	100	0.00
99M1603A	76.14	69.61	91	7.42
99M1635*	578.60	374.59	65	0.16
99M1652*	333.20	333.20	100	0.00

99M1708A	325.90	326.19	100	0.24
99M1718A	333.32	0.45	0	0.48
99M1764	320.20	5.16	2	3.89
99M1860A	133.00	121.00	91	7.77
99M1880A*	222.81	222.81	100	0.00
99M1923	65.27	63.20	97	10.40
99M2209	461.36	4.88	1	0.31
99M2210	60.16	1.95	3	1.92
99M2280A*	54.15	54.15	100	0.00
99M2282	108.10	25.90	24	2.95
99M2292	26.49	1.65	6	1.44
99M2373A*	60.26	60.26	100	0.00
99M2387*	105.40	105.40	100	0.00
99M2464*	59.65	59.65	100	0.00
99M2481	7.53	13.73	182	10.39
99M2509A*	373.22	373.22	100	0.00
99M2541*	54.19	0.00	0	0.00
99M2574	351.70	351.86	100	0.23
99M2621A	85.47	9.97	12	7.55
99M2684A	665.80	667.88	100	1.48
Total number of actual missions			44	
Total number of false missions			15	
Total number of missions			59	

Note 1. Negative numbers are shown in parentheses.
Note 2. False Missions are annotated with an asterisk (*)
Note 3. The above data was derived from the 1999 mission records of the AFRCC. (AFRCC Mission Records, 1999)

APPENDIX D

TABLE 4

Table 4

Results of Using Revised Second Area

Mission Number	Revised Area Two Aircraft Located
99M0011A	Yes
99M0046A	Yes
99M0076	Yes
99M0106	No
99M0123A	Yes
99M0140A	Yes
99M0162	Yes
99M0187A	No
99M0198A	Yes
99M0244A	Yes
99M0261	Yes
99M0308A	No
99M0342A	Yes
99M0392	Yes
99M0427A*	Yes
99M0491A	Yes
99M0540A	Yes
99M0604	Yes
99M0657A	Yes
99M0729A	Yes
99M0794A	Yes
99M0851	Yes
99M0860A	Yes
99M0892	Yes
99M0904A	Yes
99M0908	Yes
99M0920A*	Yes
99M1090A*	Yes
99M1013A*	No
99M1119*	Yes
99M1152A	Yes
99M1179*	Yes
99M1180	No
99M1192	Yes
99M1202A	Yes
99M1231A	Yes
99M1313A	Yes
99M1448A	Yes

99M1470A	Yes
99M1476	Yes
99M1510	Yes
99M1539A	Yes
99M1566*	Yes
99M1603A	Yes
99M1614	Yes
99M1635*	Yes
99M1652*	Yes
99M1692	Yes
99M1708A	Yes
99M1718A	Yes
99M1726A	No
99M1764	Yes
99M1860A	Yes
99M1880A*	Yes
99M1910A	Yes
99M1923	Yes
99M1939	No
99M2085	Yes
99M2209	Yes
99M2210	Yes
99M2280A*	Yes
99M2282	Yes
99M2292	Yes
99M2322	No
99M2360	No
99M2373A*	Yes
99M2387*	Yes
99M2464*	Yes
99M2481	Yes
99M2509A*	Yes
99M2541*	Yes
99M2574	Yes
99M2611A	No
99M2621A	Yes
99M2636A	No
99M2684A	Yes
99M2703	No
99M2712	Yes

Note 1. False Missions are annotated with an asterisk (*)
Note 2. The above data was derived from the 1999 mission records of the AFRCC. (AFRCC Mission Records, 1999)

APPENDIX E

TABLE 6

Table 6

Missions in the Project Study Having Updated LKPs

Mission Number	LKP Distance to Final Location in Nautical Miles	Type of LKP
99M0011A	0.78	NTAP
99M0046A	7.95	Radar
99M0106	0.6	NTAP
99M0140A	8.41	Radar
99M0198A	6.67	Radar
99M0244A	112.2	Tower Visual
99M0308A	104.5	NTAP
99M0342A	0	NTAP
99M0657A	40.82	NTAP
99M0729A	0	Pilot Communication
99M0794A	0.78	NTAP
99M0892	23.29	Radar
99M1119	66.66	Pilot Communication
99M1152A	12.51	Radar
99M1313A	1.07	Radar
99M1476	28.41	Radar
99M1510	0.45	Radar
99M1539A	46.18	Radar
99M1566*	17.4	Radar
99M1603A	0	Radar
99M1652*	91.9	Radar
99M1692	141.6	NTAP
99M1764	6	Pilot Communication
99M1860A	1.2	NTAP
99M1880A*	220.7	Pilot Communication
99M2209	4.87	Pilot Communication
99M2280A*	37.45	Radar
99M2611A	0.6	Radar
99M2684A	2.36	Radar
Total Mean distance from LKP to Final Location		33.98 Nautical Miles
Total Mean Distance from LKP to Final Location Excluding False Missions		24.72 Nautical Miles

Note. False Missions are annotated with an asterisk (*)
Note 2. The above data was derived from the 1999 mission records of the AFRCC. (AFRCC Mission Records, 1999)