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Factors Which Decrease the Search Time of an Aircraft Crash

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FACTORS WHICH DECREASE THE SEARCH TIME OF AN AIRCRAFT CRASH

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CHAPTER I

INTRODUCTION

Over the past several years, increased attention has been devoted to the timeliness of aircraft searches. One of the most notable missions occurred in April 1997, when an A-10 military aircraft was lost over the Colorado Rockies ("Searchers," 1997). Despite the intensive search efforts by both military and civilian organizations, the wreckage was not located for more than 18 days. Meanwhile, the pilot had long since succumbed to injuries sustained during the crash and exposure to the severe cold ("Searchers," 1997).

Such anecdotes are becoming increasingly common in the aviation community. A report from the Federal Air Surgeon General's Bulletin cited the average search time for locating an aircraft varies between 6.8 and 42.4 hours following a crash (Shaw, 2003). The report further indicates a scarce likelihood of post-crash survival after the initial 24 hours if victims are severely injured (Shaw, 2003). In 2002, the Air Force Rescue Coordination Center (AFRCC) initiated search missions for more than 113 downed aircraft in distress ("Air," 2002). On 44 of those 113 searches (39 percent), rescuers found the occupants of the aircraft deceased upon locating the crash site ("Air," 2002). Lt Col Mark Fowler of the AFRCC cites that only 35 percent of victims survive the initial impact of an aircraft crash; furthermore, 60 percent of those victims are injured and can survive for only about 24 hours (Schiff, 1999). Lt Col Fowler further explains that the other 40 percent of [uninjured] victims have a "half-life" of about 3 days [due to exposure] (Schiff, 1999). (A victim's "half life" describes how long it takes for half of a population of victims to perish). Based on these findings, even those lucky enough to survive an aircraft crash can expect a long wait before rescue personnel can locate the scene; such delays can further deteriorate the probability of survival for injured crew or passengers.

Purpose of the Study

The purpose of this study is to determine what procedures a general aviation aircrew can perform during the course of flight to minimize the search time required to locate the aircraft's crash site in the event of aerial disaster. This study will also serve to quantify the extent each procedure can reduce the overall search time. Findings from this study can then be used to educate pilots to practice these "crash-conscious" procedures and improve post-crash aircrew survivability.

Statement of the Problem

According to the Federal Air Surgeon's Medical Bulletin, the average search time to locate the occupants of an aircraft following a crash in which injuries are sustained generally exceeds victims' window of survivability (Shaw, 2003). This deficiency in the general aviation system has resulted in a significant and needless loss of aircrew members and flying passengers alike. The impact of continued general aviation fatalities due to lengthy searches and delayed recovery and medical treatment of crash victims mandates that studies be conducted to discover practices to alleviate this problem.

Significance of the Study

Although much information is available about *how* to survive following a crash, relatively few studies exist to show pilots how to maximize their potential for being located *even before a problem exists*. Only about 14 percent of aircraft accident victims are fortunate enough to avoid injury; a majority of crash victims are killed or injured (Schiff, 1999). In the event that the injuries sustained during an aircraft crash are incapacitating, the survivors may have limited (or no) capability to perform post-accident procedures to assist rescuers locate the scene. Aircrews should be obligated to ensure safe operations and prepare for emergency situations such as ensuring ELTs are in working order and flight plans are filed prior to takeoff.

Many pilots do not realize the potential benefits of using available *free* safety services such as flight plans and ATC radar following. Since a majority of general aviation pilots have likely never been involved in an aircraft accident, they may not understand the unintentional delays they could be imposing on a search by not using such safety measures. Clearly, pilots need to be educated that a properly filed flight plan, an operational ELT, and early communication can aid in reducing the response time of rescue assets in an aircraft emergency (Shaw, 1999). Creating "crash conscious" pilots with the knowledge to use practices that could provide accurate positioning information in an emergency will undoubtedly minimize fatalities resulting from untimely rescue.

Research Questions

The following research questions are posed:

1) To what extent does filing a flight plan decrease

overall search time following a general aviation aircraft crash?

2) To what degree does participation in optional ATC radar services (such as flight following) decrease search time following a general aviation aircraft crash?
3) To what extent does an operable Emergency Locator Transmitter (ELT) decrease search time following a general aviation aircraft crash?
4) On average, how long does it take to locate a crashed aircraft that does not file a flight plan, utilize Air Traffic Control's flight following service, or have an operable ELT on board?

Theoretical Framework

General aviation aircraft are not required to file VFR flight plans, participate in optional Air Traffic Control radar services (such as flight following), or even disclose their intended route of flight. Without such basic information, searchers have little hope of pinpointing an accurate last known position (LKP) of such an aircraft. This inability to limit search parameters results in a considerably larger search area; thus, a lack of basic flight information (such as aircraft routing, performance data, etc) merely perpetuates searches. Furthermore, aircraft flying without a flight plan risk delaying a search significantly since search actions will not be initiated unless the aircraft is reported missing by an outside source ("Search 2," n.d.). Even with an ELT aboard, general aviation aircraft still risk lengthy searches; one study concluded that ELT failure rates were as high as 75 percent (Lukowski & Charbonneau, n.d.).

Although regularly filing flight plans and participating in optional services such as ATC flight following does not guarantee a rapid rescue, such procedures do expedite search efforts (Shaw, 2003). In the event of an aerial accident, searchers can use the information provided by these flight services to expediently limit the confines of the search to an area with the highest probability of the target's location ("Search 1," n.d.). Conclusively, a concentrated search in an area of high target probability will result in a more rapid find than a decentralized search across a large search area.

These arguments operate under the *Decision Theory*, a management-based theory which states that the more information a manager has, the better his decisions will be. Likewise, this theory can be applied to search and rescue (SAR) specialists. The more information a SAR planner has about an aircraft target such as LKP, track, range, etc., the better able that search and rescue manager is to deploy resources in high-probability search areas. Based on the Shaw (2003) study, search and rescue decisions founded on an abundance of information appear more effective than those based on guessing alone. Thus, the more information the searchers possess, the more rapidly a target should be located.

Definitions

The following terms are defined as they relate to this study:

Air Route Traffic Control Center (ARTCC) - any enroute Air Traffic Control facility engaging in manual or radar separation of aircraft.

Emergency Locator Transmitter (ELT) - A transmitter on an aircraft actuated manually or automatically that is used as an alerting and locating aid for survival purposes.

LKP - Last known position of an aircraft; based on a pilot's self reported position or reliable observation

SAR - Search and Rescue; federal, state, or local resources tasked with locating and providing assistance to downed aircraft.

Flight Plan (VFR) - an optional, pilot-reported plan for a flight based on known conditions and including the information prescribed in FAR 91.153.

Assumptions

1) An occupant of an aircraft following a crash in which injuries were sustained can survive no longer than 24 hours in an exposed environment without survival gear.
2) Unless otherwise indicated, all studied aircraft were equipped with an operable Emergency Locator Transmitter (ELT).
3) Pilots who file a flight plan intend to fly the route specified or regularly update their flight plan enroute if deviations occur.
4) Search crews are competent and are assumed to be of equal skill.

Limitations

Due to the overwhelming amount of the data, this study is unable to account for the effect of terrain features on search times: terrain can have a profound effect on the ability of search teams to locate ELTs or other electronic locating devices. Additionally, this study does not address the time requirements for ground crews to maneuver over terrain and ground obstacles to reach the crash scene. Aircraft color schematics, fires, or other devices designed to increase the visibility of an accident scene are not taken into account. The application of specific search procedures is not studied, nor is the skills and experience of the search teams. Since only general aviation aircraft are included in this study, it is not possible to apply the findings of this report to commercial aviation, air cargo, and other operations using large (wide-body, jet) aircraft. In a practical sense, these factors are pivotal to developing a complete understanding for significant differences in search times. Although these facets of search and rescue are not addressed in this research project, further study of these topics is warranted.

CHAPTER II

REVIEW OF LITERATURE

Although several mathematical and statistical formulas have been developed that outline the methodologies of determining the time required to locate an (aerial) search target, relatively few true research studies have been conducted on the topic. The most commonly accepted search time formulas are relatively standardized across the search and rescue community and are included in almost every major international and domestic SAR manual. These equations, however, are no more than mathematical probability models that manipulate search time requirements as a function of search area, resource capabilities, and detection probabilities. Few contain any raw data for examination and fail to list their research methodologies for evaluation. No study to date was found to account for the "layered" effect of flight plans, radar coverage, and ELT operability. However, some studies have conducted research exploring the effect of search time requirements as a function of one of the factors.

Review and Critique of Related Studies/Literature

Shaw's (2003) study of search time requirements of aircraft most closely represents the foundation of this study. In his research, Shaw (2003) accounts for the average search time required to locate a crashed air target based on the presence and type of flight plan filed by the pilot. Shaw determined the average time required to locate aircraft filed under IFR and VFR flight plans. Additionally Shaw also explored the time requirements to locate aircraft not filing a flight plan. It was discovered that aircraft flying under an IFR or VFR flight plan required a mean search time of 13.1 hours and 37.3 hours respectively (Shaw, 2003). Those aircraft flying without an active flight plan required an average of 42.4 hours to locate (Shaw, 2003). In addition to analyzing the search time means as a function of flight plans, Shaw also conducted a secondary study that found the mean search time required to locate aircraft on the basis of ELT operability (2003). The results of the study yielded dramatic search time differences - 40.7 hours without an operable ELT verses a mere 6.8 hours if the aircraft's ELT was functioning (Shaw, 2003). These mean search times, however, cannot be used as more than ordinal information to guide future research, as Shaw's study fails to provide continuity. No data or methodology is contained in Shaw's study to determine its reliability or verify his findings. Shaw's research, unfortunately, did not account for the synergistic effects of having a flight plan in conjunction with radar coverage *and* an operable ELT; this study will serve as a furtherance of Shaw's original work.

Flight Plans

Free flight plan filing, a specialized FAA/FSS service plays a significant role in determining search time requirements. Aerial or ground searches for a downed air target are significantly delayed if the target aircraft failed to file a flight plan ("Search 2", n.d.). The protection provided by filing a flight plan ensures that initial search procedures are initiated after only 30 minutes has elapsed after an aircraft's projected estimated time of arrival at the filed destination ("Search 1", n.d.). These procedures include interrogatory messages sent to airports, ATC facilities, flight service stations, and other applicable aviation entities to attempt rapid location of the aircraft ("Search 1", n.d.). If after two hours preliminary searches are unsuccessful, a full search is initiated involving civil and military SAR resources ("Search 2", n.d.). Preliminary searches are not initiated for individuals not flying on a flight plan until at least one hour after the projected ETA of the aircraft; these steps are only taken after the aircraft is reported missing by a reliable source ("Search 1", n.d.). According to an Air Force review of more than 325 SAR missions, an average of more than 36 hours pass before a concerned family member initiates such an alert to SAR resources ("Emergency Services", n.d.). In the event that a pilot fails to inform anyone of his flight plans, search efforts could conceivably be delayed almost indefinitely. The obvious search delays caused by a pilot failing to file a flight plan reflect the findings of the Shaw (2003) study that aircraft flying on a flight plan are generally found much more rapidly than those flying without a filed plan.

Emergency Locator Transmitters

Another safety device used to reduce both search area and search time is the Emergency Locator Transmitter (ELT). This device, which has also become known as the Crash Position Indicator (CPI) emits a signal which can be received by ground search stations, satellites, and rescue personnel with specialized equipment. Generally, these devices are mandatory on most commercial and private aircraft registered in the United States ("Department" 3-3, 1986). Independent of radar transponders, the ELT devices are subject to activation either manually or when subjected to a pre-set change in G-forces ("Department" 3-3, 1986). The reception of such an emergency signal can often initiate a search, however, without other indicators of a lost aircraft, it is standard practice for searchers to wait for multiple confirmations of ELT signals to ensure those signals are indeed genuine ("Emergency Services"). This response delay is required to prevent abusing SAR resources since only about one percent of all ELT activations are actual emergencies (Schiff, 1999). Due to the orbital mechanics of the SARSAT system, the acquisition of two ELT "hits" requires a minimum of 100 minutes ("Emergency Locator"). A new ELT development known as the 406 MHz transmitter, allows immediate confirmation for rescuers and is more accurate than traditional models (Schiff, 1999). ELTs are required to operate for a minimum of 48 hours giving searchers a short timeframe to nearly pinpoint the search target ("Emergency Locator"). Unfortunately, ELT reliability can be poor since the device can be damaged from the aircraft impact. As a general rule, "ELTs survive only when the victims do" according to Brandon Brown, Texas Wing Director of Emergency Services, CAP (Schiff, 1999). One study calculated ELT failure rates to be as high as 75 percent (Lukowski & Charbonneau). One major drawback of ELTs is that they transmit line-of-sight signals. Terrain shielding and other factors may degrade the effectiveness of ELT searches, especially in areas of high terrain ("National", 5.17, 1998). Since ELTs can be used to both pinpoint a general location of the search target and inform SAR resources of an emergency (independent of a flight plan), ELTs are a valuable resource in minimizing the time required for aircraft searches.

Radar Coverage

In general aviation operations, participation in optional radar "flight following" services is another safety net to provide searchers with additional information in the event an aircraft crash. As a general rule, Air Route Traffic Control Centers and Flight Service Stations providing radar coverage to aircraft under flight following conditions may consider a loss of radar contact or terminated contact with the facility to constitute an emergency ("Emergency Services"). Under such circumstances, these facilities may initiate the deployment of SAR resources. One additional benefit of participating in optional radar services is that such services provide searchers with vital tracking information during a search.

When flying on a flight plan, air traffic control facilities are queried for information (radar or radio contact) after two hours following the aircraft's projected ETA ("Search 2").

Summary

Thus, an overall lack of information specific to determining search times based on variables such as filed flight plans, radar coverage, or ELT operability, many literary sources indicated independent positive results from practicing any one of the previously mentioned safety procedures.

Given the results of Shaw's study of general aviation search times, the use of flight plans clearly result in a significant decrease in search time (2003). After briefly analyzing the operational procedures applicable to aerial search and rescue activities, it becomes vividly apparent that a pilot's failure to file a flight plan dramatically delays the initiation of search efforts under current FAA SAR practices ("Search 2").

Shaw's research solidifies the notion that an operable ELT also dramatically contributes to decreasing the required search time of an aircraft; moreover, the results of Shaw's study indicates that ELTs lessen search time significantly even when compared with the mean average of those on a filed flight plan (2003). Although ELTs are excellent search tools and have been found to significantly reduce search times through their unique ability to pinpoint crash sites, ELTs do have several drawbacks. ELTs do not function well in adverse terrain because of reflection or signal blocking; additionally, ELT transmitters are susceptible to damage from the initial aircraft impact ("National", 5.17, 1998).

Although there is a general lack of information or applicable studies directly relating air traffic control radar use to search and rescue operations, ARTCC and FSS stations have defined procedures in the search and rescue process ("Emergency Services"). Primarily, ATC facilities are tasked with augmenting flight information to search and rescue workers through the utilization of radar history tapes and aircraft contact records ("Emergency Services").

CHAPTER III

METHODOLOGY OF THE STUDY

The purpose of this study is to determine procedures and practices a general aviation aircrew can perform in flight to reduce search time in the event of a crash. Archival data was used for this study and was acquired from a national search and rescue database courtesy of Civil Air Patrol (Maxwell AFB, AL) and the Air Force Rescue Coordination Center (Langley, VA).

Population

The population for this study was limited to all civil (both commercial and private) aircraft crashes that occurred in the United States or were otherwise coordinated by the Air Force Rescue Coordination Center. The study was unable to differentiate according to pilot certification level, experience, or type of operations flown due to the limited data manipulation capability of the AFRCC computer database and the study's own time constraints.

Sample

The sample for this study was acquired from the archival records database of actual search and rescue missions conducted by the Air Force Rescue Coordination

Center between January 2000 and July 2003. Since the database contains raw search data that includes lost individuals, naval vessels and military aircraft, those applicable records will be subsequently ignored for the purposes of the study. Search data from all regions of the country will be used in the study to reduce disparity due to terrain factors. Only data from the time span indicated will be used to most accurately account for advances in search and rescue procedures and establish current search information. Additionally, only searches that resulted in the aircraft being located will be used; thus, missions that were suspended or cancelled will not be used in the data acquisition process, per se (although this information will provide descriptive information about the number of search mission "failures"). The indicated three years and seven months of recorded data was chosen due to its rapid accessibility from the AFRCC database and the convenience of acquisition from AFRCC personnel.

Study Design

This study employs a non-experimental descriptive design which uses archival data acquired from the Air Force Rescue Coordination Center (AFRCC). All search and rescue missions conducted during the study's timeframe (January

2000 - July 2002) that involved aircraft and were adequately documented by the AFRCC to include all applicable information required by this study were included.

Data Collection Method

Archival data were collected by the HQ Civil Air Patrol Emergency Services Division (Maxwell AFB, AL). The Civil Air Patrol maintains a liaison with the Air Force Rescue Coordination Center and can readily access archived search and rescue data. Data collected from the database included the AFRCC incident number (used for identification purposes); the presence or absence of flight plans, radar usage, and operable ELTs; mission start time; resource launch time; and mission end time.

Instrument Reliability and Validity

Based on preliminary statistics from the 2002 AFRCC Annual Report, 104 aircraft search missions and more than 2,500 ELT missions (not all were necessarily aircraft ELTs) were recorded ("Air Force", 2002). Since the instrument of data acquisition is the archival records of the AFRCC, the experiment has a high degree of reliability. The major threat to the instrument's reliability is the need to discard reports in which lost aircraft were never located.

If data of even a few of such search missions were included, the results of the study would be greatly skewed outside the range of practical use. Slight variations may occur between multiple studies, however, due to the large sample size, reliability should remain high unless general aviation experiences dramatic shifts in aviation accidents or search procedures.

It has been determined through the Shaw (2003) studies that flight plans and operational ELTs each yield a significant improvement of search time over aircraft not utilizing these preventative measures. Although the Shaw (2003) research only provided average numbers for aircraft using flight plans and ELTs, the results of using such means clearly indicates a decrease in search time. The results of the Shaw (2003) study support the validity of this study for both ELT usage and filing of flight plans. Although radar usage is not directly addressed in the Shaw (2003) study, it can be inferred that this is another degree of information that directly influences search time because of the valuable information it provides searchers (since the information is similar to that provided by flight plans and ELTs).

Data Analysis

Data was analyzed using a single sample T-test design. The independent variables are dichotomous and include the presence or absence of a VFR flight plan, flight following (or other ATC radar usage), and ELT initial notification (indicating an operable ELT) with the dependent variable being search time. Search time was defined as time spanned between the launch of the first mission SAR resource (aircraft, ground team, etc) and physically locating the target. Each condition will be evaluated separately, independent of all other conditions. After entering the applicable data into a statistical computer package (SPSS v. 10), the results will be determined from the significance analysis of each condition based on a statistical significance standard (i.e. $p = .05$). Additionally, each group's mean (average) values also provided descriptive data. T-tests were performed twice with the data provided. The first analysis included all data provided without altercation. The second analysis included all data except those determined to be statistical outliers that will obviously skew the results of the study. The findings of both analyses were compared for both significance changes and mean changes (of the dependent variable). The composite results of both analyses were used to determine overall results and support conclusions of the study.

Protection of Human Subjects

The data acquired for this study is public information and available to the public on request from the Air Force Rescue Coordination Center via the Freedom of Information Act (FOIA). Data provided for this study was in no way linked to any individual, aircraft, or entity and contained solely coded entries which were not identifiable to the researcher. Since all information was archival, subjects were not contacted to release information. Additionally, an experienced aviation researcher reviewed the study methodology and periodically during its execution to ensure the protection of human subjects.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

This study investigated preventative procedures that an aircrew can perform during the course of flight that could reduce the search time required to locate that aircraft in the event of a crash. The procedures studied included the filing of VFR flight plans, use of ATC radar flight following, and the carriage of an operational (and properly maintained) Emergency Locator Transmitter. Descriptive statistics were used to analyze the data for each condition of the independent variables. The interaction of those variables was not assessed in this study. The data provides insight to the following research questions:

1) To what extent does filing a flight plan decrease overall search time following a general aviation aircraft crash?

2) To what degree does participation in optional ATC radar services (such as flight following) decrease search time following a general aviation aircraft crash?

3) To what extent do does an operable Emergency Locator Transmitter (ELT) decrease search time following a

general aviation aircraft crash?

4) On average, how long does it take to locate a crashed aircraft that does not file a flight plan, utilize Air Traffic Control's flight following service, or have an operable ELT onboard?

Sample

The sample consisted of the culmination of actual search and rescue missions derived from the archival records from the Air Force Rescue Coordination Center's computer database from January 2000 to July 2003 that conformed to the study's design criteria. Of the several thousands of records in the AFRCC database, only 149 missions contained all the required data to make an effective analysis. The sample was somewhat limiting in certain areas because a majority of the aggregate data divided disproportionately into the various study groups. Of the sample's 149 data sets, only 13 - 20 percent (n=20, n=30) of the data indicated positive usage of flight plans, flight following, and ELTs. The limited number of "positive condition" data sets was debilitating to the study because it bordered the minimum requirement to assure statistical significance (defined as n=30). Additionally, a small portion of the data contained extremely inflated search times in relation to a majority of the data, which likely skewed results. To make up for this deficiency, the analysis was conducted twice for each condition set (6 T-Tests). The first analysis was conducted with statistical outliers included in the data results; and, the second analysis eliminated obvious statistical outliers appropriately. The removal of these outliers caused the statistical significance of the data to be further deteriorated, thus reducing positive condition data sets for flight plan usage, VFR flight filing, and ELT notification to n=20, n=29, and n=30, respectively. The researcher chose to exclude 6.7 percent (n=10) of the total data sets from the second study as statistical outliers. Specific exclusions are explained in detail in the data sets spreadsheet included in the appendix of this document.

Data & Analysis: T-Test Flight Plan v. No Flight Plan

Subsequent evaluation of the data retrieved from the first set of T-tests revealed many interesting results. Surprisingly, the T-test indicated extremely strong significance between the differences of both conditions when tested at the p = .05 (alpha) level. Specific significance values for the independent variable (under the T-Test including statistical outliers) indicated the effect of flight plan to be T = 3.598 (sig = .002). The results of the first test (outliers included) found that those who filed flight plans were located in a mean time of 15.1 hours, whereas those who failed to file flight plans were found at a mean time of nearly 38.1 hours.

The second test, conducted without statistical outliers, yielded some rather fascinating results. With the exclusion of 10 erroneous data sets from the T-test calculation, many statistics were significantly altered. Like the first analysis, however, the statistical significance of this test is reduced because it even further deflated the number of data sets (n = 20) for the positive condition. The second T-test not only verified, but strengthened the "T" value of the condition. Significance values for the new T-test resulted in the positive effect of flight plan (T = 3.651, Sig = .002). With the removal of the outliers, the mean values for each condition changed to reflect a mean search time 15.8 hours for those who filed flight plans and 23.9 hours for those who did not.

Data & Analysis: T-Test Flight Following v. Absent Condition

T-tests for the flight following test were conducted in the same manner as the previous test. Results of the first T-test (with outliers) indicated strong significance between the means with "T" value of T = 5.975 (Sig < .001) for the positive use of flight following. "N" values for this test were more stable with 30 data sets for the positive condition and 119 sets for the null making the statistics more solid. The average search times for the first test showed that aircraft utilizing radar flight following were found in a mean time of 12.0 hours verses 41.3 hours for those not requesting flight following services.

The second T-test verified the results of the first with some minor changes. Ten data sets were again omitted which resulted in a strengthened "T" value and relatively major changes in mean search time values. The "T" value for the second test was T = 6.090 (Sig < .001) for the positive condition of flight following. Since a majority of the outliers were removed from the absent condition, mean values for the lack of flight following changed the most dramatically. The second test revealed the new mean search time values to be 12.4 hours for aircraft using flight following and 25.9 hours for the null condition.

Data & Analysis: T-Test ELT v. Absent Condition

ELT data from the first test (with outliers) indicated a strong significant difference between the means. The value of "T" for the condition of ELT operation was T = 6.181 (Sig < .001). The T-test indicated average search times of 12.2 hours for ELTs that operated successfully and 40.0 hours for those that did not activate (or were not aboard the aircraft).

The second T-test's results bore resemblance to the first. Since no outliers were removed from the positive condition (n = 30), the second T-test remains as statistically sound as the first test. Significance values were altered to T = 6.181 (Sig < .001). With the removal of the outliers, the new search time means were found to be 12.2 hours for ELT activation and 25.3 hours for the lack of ELT carriage or activation.

Data & Analysis: T-Test Null Set v. One or More Conditions

To further illustrate the importance of using the preceding practices (ELTs, flight plans, or flight following), this researcher chose to conduct an additional test which compared the effects (in terms of search time) of employing one or more of the practices verses not practicing any. This test was only conducted once (with outliers removed) and revealed strong significant differences between the means. The significance value was found to be T = 8.275

(Sig < .001) for practicing one or more of the "crash conscious" conditions. Practicing crash conscious conditions revealed an average search time of only 13.9 hours verses 32.2 hours for the null.

Research Question 1

"To what extent does filing a flight plan decrease the overall search time following a general aviation aircraft crash?"

To adequately answer this question given the data, the search time of an aircraft with a flight plan must be evaluated independent of all other conditions. Based on the T-test conducted that evaluates the means between the use of flight plans verses the null condition, the effect of filing a flight plan has at least an 8.1 hour improvement of search time (based on the T-test conducted with outliers excluded). In reality, this figure may be much higher when considering that a majority of the outliers were removed from the null condition. Although the minimum improvement may be nearly 8 hours, the maximum improvement in some extreme cases may be 23 hours (or more) as the initial T-test (with outliers) suggests.

Research Question 2

-*"To what degree does participation in optional ATC* *radar services (such as flight following) decrease search time following a general aviation aircraft crash?"*

Following with the same format and logic that derived the answer to research question 1, the mean search time of radar "flight following" will be analyzed independently of all other conditions. Based on the mean values for test 1 (irrespective of all other conditions), aircraft with only flight following were located in a mean of 12.0 hours verses 41.3 hours for aircraft not participating in flight following. Test 2 confirmed these results and was only slightly variant at 12.4 hours for aircraft with flight following and 25.9 hours for those not requesting flight following services. These values show an improvement in search times by more than 50 percent in both tests. Specifically, the range of positive effect likely is between a 13 to 29 hours improvement in search time.

Research Question 3

-*"To what extent does an operable Emergency Locator Transmitter (ELT) decrease search time following a general aviation aircraft crash?"*

Like the other research questions, the effect of the presence of an ELT can be determined by comparing the means between the main effect condition (without regard to the other conditions) and the null condition. The mean values for the affirmative condition of ELTs for both test 1 and test 2 was found to be 12.2 hours. Based on the predetermined null conditions set as 40.0 hours (test 1) and 25.3 hours (test 2), the effect of ELTs reduces the search time by nearly 50 percent - comparable to the effect of flight following. The effects on search time based solely on ELT operability are comparable to that of flight following - nearly a 13 hour improvement.

Research Question 4

-*"On average, how long does it take to locate a crashed aircraft that does not file a flight plan, utilize Air Traffic Control's flight following service, or have an operable ELT onboard ?"*

According to T-test which evaluated the null condition (presented on page 29), the mean time to locate an aircraft that does not participate in flight following services, file a flight plan, or carry an operable ELT is about 32.2 hours. These numbers, unlike most other conditions are relatively strong statistics with "N" values in excess of 60 for both conditions. Since 8 "high-end" outliers were removed from the null condition of the T-test, there is an indication that the absence of flight plans, flight following, or ELTs results in a minority of searches that are significantly extended. The removal of the outliers does present an over-idealized value for the test since a small, but still significant minority of searches will result in extreme search times. Conclusively, the most accurate search time range under the specified conditions is most likely to be slightly higher than 32.2 hours, when considering extreme cases.

CHAPTER V

SUMMARY, CONCLUSIONS, & RECOMMENDATIONS

The purpose of this study was to determine practices that a flight crew could perform while in the course of flight that would improve post-crash survivability by reducing the search time required to locate the downed aircraft. The statistical analysis were conclusive; filing flight plans, utilizing ATC flight following, and carrying ELTs aboard aircraft all contributed significantly to a crashed aircraft being located in an expeditious manner.

Summary

Interestingly, the statistics acquired by this study almost identically mirrored the findings of the Shaw (2003) study. Shaw found that the mean search time required to locate an aircraft that filed a VFR or IFR flight plan was 13.1 hours; those aircraft that did not file a flight plan took as long as 37.3 hours to locate. Not surprisingly, the data from this study verified the findings of the Shaw (2003) study citing the time to locate an aircraft that filed a flight plan to be roughly 15.8 hours. Those that failed to file a flight plan were found in an average time between 23.9 hours (outliers removed) and 38.1 hours (with outliers); again, these figures were remarkable close to the Shaw (2003) finding of 37.3 hours for the null flight plan condition.

Shaw's (2003) secondary study regarding the operability of ELTs in relation to search time found the mean search time to locate an aircraft that had a functioning ELT beacon to be 6.8 hours. Those aircraft in which the beacon failed to be activated or simply was not carried aboard the aircraft resulted in a mean search time of more than 40.7 hours (Shaw, 2003). This researcher's study indicated aircraft with ELT operability were found in an average of 12.2 hours compared to the null condition of between 25.3 hours (outliers removed) and 40.0 hours (outliers retained).

The similar findings of both studies both point to the significant positive effects of filing flight plans and carrying an operable ELT. Although the Shaw (2003) study did not evaluate flight following, the findings of this study suggest that the usage of such ATC radar services have a similar significant impact on reducing search time following a crash.

Conclusion

With regard to the evaluated data, it is nearly conclusive that filing flight plans, participating in ATC radar flight following, and carrying properly maintained and operable Emergency Locator Transmitters are all significant contributors to reducing search time following an aircraft crash. Usage of all of these cost-effective services are highly encouraged by this researcher for all pilots based on their significant impact on search and rescue efforts.

Recommendations

Although this study determined that flight plans, flight following, and ELT operability were all independently significant in reducing post-crash search times, it was not possible to derive the synergistic effects of using any combination of these conditions with the limited data available. As such, this researcher highly recommends that a follow-on study be conducted that evaluates the significance of both the main effects and interactive effects of using combinations of the aforementioned conditions.

Additionally, the aviation community has mandated the transition to a modernized Emergency Locator Transmitter known as the 406 Mhz model. Although inadequate data exists to determine the impacts of this new system, this researcher suggests that any follow-on study to this project include the 406 Mhz model as an independent condition. Undoubtedly, the data relating to standard ELTs as derived from this study as well as the Shaw (2003) study will not accurately reflect the impacts of this new technology on aircraft search and rescue.

APPENDICES

AFRCC#	Flight Plan	Flight Following	ELT	Search Time	
101860	Y	N	N	67.883	
102777	Y	N	Y	14.816	
1100313	Y	N	N	0.1	XXXX
1101222	Y	N	N	31.1167	
1101881	Y	N	N	4.85	
1101918	Y	Y	N	5.267	
1102876	Y	N	N	62.083	
1103686	Y	N	N	8.6	
1104635	Y	Y	N	2.9	
1105781	Y	N	N	2.183	
2100123	Y	N	Y	2.176	
2100281	Y	N	N	2.1	
2100647	Y	N	N	9.483	
2102539	Y	N	Y	1.833	
2103655	Y	N	N	6.733	
2104774	Y	N	N	9.4167	
2106110	Y	Y	N	36.333	
2107291	Y	Y	N	11.95	
3100917	Y	N	N	12.4	
3100939	Y	Y	N	1.667	
3101615	Y	N	N	23.1	
100041	N	Y	N	1.9167	
100053	N	N	N	44.933	
100094	N	Y	N	5.483	
100099	N	N	N	51.7167	
100197	N	Y	N	2.9	
100282	N	Y	N	8.583	
101118	N	N	N	91.067	
102150	N	N	N	78.3833	
102331	N	Y	N	3.413	
102785	N	N	N	5.2663	
102843	N	N	N	99.583	
103279	N	N	N	0.1167	XXXX
103764	N	N	N	23.0503	
103777	N	N	N	12.866	
103786	N	N	N	46.85	
103967	N	N	N	81.633	
104814	N	N	N	292.867	Extreme Hig
104848	N	N	N	5.2167	
105343	N	N	N	10.767	
105552	N	Y	N	1.467	
106230	N	N	N	188.65	Extreme Hig
106658	N	N	N	29.6167	
106679	N	N	N	13.75	
106718	N	N	N	5.133	
106839	N	N	N	5.567	
106849	N	N	Y	15.383	
106899	N	N	N	63.267	
106960	N	N	N	11.633	
107023	N	N	Y	14.867	
1100175	N	N	Y	13.817	
1100233	N	N	N	3.33	
1100252	N	N	N	3.333	
1100374	N	N	N	110.983	
1100419	N	N	Y	8.767	

AFRCC#	Flight Plan	Flight Following	ELT	Search Time	
1100808	N	N	N	194.267	Extreme Hig
1100827	N	N	N	17.467	
1100881	N	Y	N	4.517	
1100883	N	N	N	341.417	Extreme Hig
1100926	N	N	N	1.8	
1100998	N	N	N	15.667	
1101055	N	N	N	13.583	
1101232	N	N	Y	23.083	
1101247	N	N	Y	27	
1101293	N	N	Y	1.867	
1101433	N	N	N	3.65	
1101453	N	N	Y	7.983	
1101494	N	N	Y	1.4167	
1101672	N	N	N	142.967	
1101677	N	N	N	13.6	
1101800	N	N	N	43.2	
1101811	N	Y	N	44.0167	
1101916	N	N	N	35.3167	
1102145	N	N	N	4.633	
1102306	N	Y	Y	6.15	
1102605	N	N	Y	4.6167	
1102606	N	N	N	313.5	Extreme Hig
1102953	N	N	Y	17.533	
1102995	N	N	N	378.017	Extreme Hig
1103086	N	N	N	2.95	
1103228	N	N	N	57.783	
1104276	N	Y	N	0.3167	XXXX
1104353	N	Y	N	12.15	
1104388	N	N	Y	17.75	
1105121	N	N	N	62.5	
1106087	N	N	N	1.083	
1106323	N	N	N	8.933	
1106397	N	N	N	13.333	
1106479	N	N	N	10.333	
1106590	N	N	Y	3.4167	
1106649	N	N	N	325.683	Extreme Hig
1106721	N	N	N	33.133	
1106729	N	Y	N	23.4	
1107096	N	Y	N	15.35	
1107144	N	Y	N	15.75	
2100125	N	N	Y	2.75	
2100199	N	N	N	18.267	
2100422	N	N	Y	20.233	
2100459	N	Y	N	14.617	
2100996	N	N	N	2.6167	
2101118	N	N	N	10.833	
2101161	N	N	N	45.6	
2101177	N	Y	Y	8.333	
2101602	N	N	N	87.033	
2102799	N	Y	N	10.5	
2103063	N	N	N	2.3	
2103324	N	N	N	42.6	
2103604	N	Y	Y	5.567	
2104135	N	N	N	9.7167	
2104370	N	N	N	0.767	

AFRCC#	Flight Plan	Flight Following	ELT	Search Time
2104738	N	N	Y	10.4
2104943	N	N	N	4.15
2105467	N	N	N	25.33
2105527	N	N	N	8.15
2105668	N	N	N	6.2
2105993	N	N	Y	32.5
2106039	N	N	Y	14.4167
2106063	N	N	N	22.133
2106274	N	N	N	3.383
2107031	N	N	N	8.383
2107136	N	N	N	8.85
2107373	N	N	N	36.93
3100139	N	N	N	19.4167
3100379	N	Y	N	37.35
3100413	N	N	Y	1.283
3100574	N	Y	N	7.567
3100680	N	Y	N	5.983
3100844	N	N	Y	49.8667
3100870	N	N	Y	4.567
3100953	N	N	Y	14.367
3100980	N	Y	N	19.45
3101067	N	Y	N	13.983
3101129	N	N	N	14.0833
3101150	N	Y	N	16.5167
3101362	N	N	N	48.8
3101378	N	N	N	11.483
3101922	N	Y	N	17.85
3102167	N	N	N	72.65
3102459	N	N	N	47.667
3102602	N	N	Y	15.5
3102633	N	N	N	137.267
3102654	N	N	N	5.7167
3102806	N	N	N	11.133
3102810	N	N	N	6.4167
3103105	N	N	N	176.9
3103186	N	N	Y	2.6667
3103375	N	N	N	7.6667
3103591	N	N	N	18.25
3103986	N	N	N	9.833

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