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Effect of Cellular Phone and Radar Forensics on Search and Rescue Duration for General Aviation Aircraft Accidents in the Contiguous United States

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Abstract

Emergency Locator Transmitters (ELT) are generally the primary tool for locating distressed aircrews following an aircraft accident. In 2009, the International COSPAS-SARSAT organization ordered the cessation of 121.5 MHz ELT satellite monitoring to alleviate systemic false alarms and encourage pilots to upgrade ELTs to modern 406 MHz models. While most nations acquiesced to the mandate, the United States encountered severe resistance from pilot groups. As a result, 121.5 MHz ELTs are still in use in the U.S. but remain unmonitored by satellite systems. This study sought to assess the impact of alternative search methods such as radar and cellular phone forensic analysis on search and rescue duration. The study collected records from 365 search missions conducted between 2006 and 2011 to determine if there was a significant difference in mission search durations if forensic methods were utilized. Data was transformed and assessed using ANOVA and Brown-Forsythe F-testing. The study revealed that missions which employed either cellular phone or radar forensic search methods required significantly longer than missions which did not employ those techniques. Missions utilizing cellular phone forensics required a mean of 23.4 search hours, whereas missions which did not use cellular forensic methods only required 13.2 hours. Similarly, missions using radar forensics required a mean of 21.3 hours versus 10.0 hours for missions which did not use such forensics. This research provides valuable data to search and rescue agencies in determining the efficacy of using both cellular phone and radar forensic methods in search operations.

Keywords: radar, cellular phone, forensics, triangulation, pinging, search and rescue

Introduction

The use of Emergency Locator Transmitters (ELTs) installed aboard aircraft has long been the primary method of locating distressed aviators following an aircraft accident. Despite the contributions ELTs have made to aviation search

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and rescue, the technology is not without its flaws. ELTs and the supporting COSPAS-SARSAT monitoring system have been plagued with problems since their inception in 1979. ELTs are susceptible to crash damage, which can disable their transmission capability. Moreover, the design of older 121.5 MHz ELTs suffers from limited accuracy, making them less effective than other search mediums. Finally, false alarms from inadvertently activated 121.5 MHz ELT have overwhelmed the COSPAS-SARSAT network to such a degree that the search agency discontinued satellite monitoring of this entire class of beacons.

Without reliable ELT data, aviation search and rescue personnel must rely on alternative information sources to reliably locate aircraft crash sites. Two novel procedures have evolved to augment, and in some cases, even replace ELT location data in aircraft search missions: radar and cellular phone forensic data. Rescuers can tap into recorded data from the FAA and military radar sites to track the location of missing aircraft based on their route of flight. By analyzing cellular network data records, rescuers can obtain historical and real-time location data for cellular phones carried by aircraft occupants.

ELT Survivability and False Alarms

Despite the rugged design of ELTs, crash survivability was initially a problem. Research by Hall (1980) and Trudell and Dreibelbis (1990) revealed poor post-crash survivability data for ELTs. Hall (1980) revealed ELTs were destroyed in more than 60% of crashes. Among crashes in which the ELT was destroyed, extensive searches were required to locate 31% of the crash sites (Hall, 1980). A later study of post-crash data by Trudell and Dreibelbis (1990) revealed a 61% ELT failure rate. Trudell and Dreibelbis (1990) further analyzed aircraft occupant post-crash survival as a function of ELT operation. Their results revealed that successful activation of ELTs yielded a 34% survival rate, a 15% advantage over crash victims without a functioning ELT (Trudell & Dreibelbis, 1990). An improved standard for ELTs established by the FAA in 1994, TSO-91a, increased ELT survivability marginally to 50% (Gauthier, 2009). To date, no known studies have been published documenting the survivability of modern TSO C-126, 406 MHz ELTs.

In addition to ELT survivability problems, inadvertent or non-emergency 121.5 MHz ELT activations were a constant plague to the COSPAS-SARSAT monitoring system. Research by Toth and Gershkoff (1979) reported that false alarm ELTs made up nearly 95% of all ELT activations. Trudell and Dreibelbis (1990) reported similar findings, citing up to 97% of ELT activations were non-distress events. The U.S. Coast Guard (n.d.) reported that the U.S. Mission Control Center received 250–400 121.5 MHz

beacon signals each day, of which 99.9% were false alarms. As a result of the excessive number of inadvertent 121.5 MHz ELT activations, it became standard operating procedure for search agencies to delay deploying search resources until the signal was verified by successive COSPAS-SARSAT satellite passes, a process requiring up to 100 minutes (Federal Aviation Administration [FAA], 2012; COSPAS-SARSAT, 2009b).

Cessation of 121.5 MHz ELT Monitoring

To curb the quantity of ELT false alarms, the International COSPAS-SARSAT organization announced the cessation of 121.5 MHz ELT monitoring beginning on February 1, 2009 (COSPAS-SARSAT, 2009a). This measure was designed to hasten pilot transition to newer, more accurate 406 MHz ELT beacons (COSPAS-SARSAT, 2009a). Most nations followed the COSPAS-SARSAT organization's lead and mandated ELT model replacement; however, the United States did not. The Federal Communications Commission (FCC) attempted to enact regulatory mandates to phase out 121.5 MHz beacons; however, the agency encountered fierce resistance from pilot advocacy groups (Aircraft Owners and Pilots Association [AOPA], 2011). AOPA argued that 121.5 MHz ELTs were still viable, and highlighted the limited availability of 406 MHz models (AOPA, 2011). The FAA sided with AOPA, warning that the cost to equip 406 MHz ELTs across the nation's 200,000 general aviation fleet could top more than \$500 million (Brown, 2013). In 2013, the FCC issued a revised proposal to halt the manufacturing of 121.5 MHz ELTs, but this move was again met with AOPA resistance (Brown, 2013). To date, regulations restricting the use and manufacture of 121.5 MHz ELTs remain unchanged.

With the lack of satellite monitoring for 121.5 MHz ELTs, aviation search and rescue personnel must rely on alternative means for detecting and locating distressed aircraft.

Radar Forensic Analysis

Radar forensic analysis relies on the fusion of data from multiple radar sites, air traffic control recordings, NEXRAD weather data, and other sources. Assessment of radar information is conducted by members of the U.S. Air Force's 84th Radar Evaluation Squadron (RADES) and a small group of specialized volunteer members of the Civil Air Patrol (NSARC, 2011). The methods utilized by the 84th RADES analysts are not publicly available; however, J. Henderson, an 84th RADES radar analyst, agreed to describe the process in an interview conducted on April 22, 2013. Another radar analysis specialist from the Civil Air Patrol provided further forensic background information in an interview conducted on April 23, 2013, but requested anonymity.

Radar analysts access radar data recorded from more than 300 military and civilian radar sites connected to the Western Air Defense Sector (WADS). Additionally, analysts request data from radar sites not participating in the WADS recording system, when available. Analysts start by locating the aircraft of interest in the radar recording and record significant changes in the aircraft's status. They note changes in transponder settings, altitude, and loss of primary or secondary radar information. Additionally, analysts add data overlays to the radar information such as terrain maps, airspace, search grids, radar coverage plots, and NEXRAD weather reports. Radar data from multiple radar sites can be interlaced and even synchronized with recorded air traffic control recordings. Henderson states, "By comparing the target aircraft's route of flight against radar coverage overlays, analysts can confine a search area. Not detecting an aircraft where it is expected to be and where radar coverage is good is a search indicator" (personal communication, April 22, 2013). Search clues can be also be derived by "evaluating uncharacteristic pilot behaviors and identifying why they are occurring" (radar analyst, personal communication, April 23, 2013).

Radar analysts use a powerful data integration tool dubbed Tactical Mapping. This proprietary software was engineered by one of the forensic team's senior radar analysts. The software is capable of reading 12 different radar data formats from military, civilian, and international agencies. The power of the program lies in its ability to overlay multiple data layers and filter extraneous information, based on operator search parameters.

The effectiveness of radar forensic search techniques is affected by several factors. To generate radar forensic data, aircraft must enter a radar coverage area. Generally, radars are relatively ineffective at low altitude, unless the target aircraft is near the radar transmitter. Additionally, low flying aircraft may not intersect enough radar coverage zones to generate useful forensic data. Radar coverage is often concentrated near airports around population centers and areas of high density air traffic. An aircraft's chances for radar forensic detection and effective tracking are improved as the aircraft enters additional radar coverage areas; this is particularly true in areas with multiple radars of overlapping coverage. Additionally, the size of the aircraft is also an important consideration, as larger aircraft create a proportionally larger radar signature. Excessively low aircraft speed also affects radar detection. This factor is especially important for Pulse-Doppler radars, as many of these systems automatically filter low range-rate targets to reduce operator scope clutter. It is especially helpful to radar forensic searches if aircraft activate their onboard Mode C transponder, as this allows radar forensic analysts to positively identify the aircraft and simplifies the forensic data collection process. Ultimately, these factors most often determine the success of a radar forensic search.

Cellular Phone Forensic Analysis

Like radar forensic analysis, there is little public or non-proprietary documentation available to review. As a result, expert interviews were used to formulate critical background for the study in lieu of published literature. B. Ready and J. Ogden, cellular phone analysis experts from the Civil Air Patrol, agreed to describe the cellular phone forensic analysis process in an interview conducted on April 30, 2013.

Upon receiving a support request, cellular forensic analysts begin by determining the target cellular phone's servicing company. If the provider is not known, a "portability database" or online repository of cellular phone servicing data is used to lookup the phone's service provider. Analysts then assess the target aircraft's expected route of flight and determine where it intersects cellular coverage areas, and the accompanying cellular service towers. Analysts submit a special data request to the servicing cellular phone provider and applicable roaming tower owners for cellular phone parametric usage data. Forensic information can alert analysts to which sector, or wedge of the cellular tower's antenna was used to communicate with the target cellular phone. Cellular phone forensic analysis is often carried out in tandem with radar forensic analysis, using the same Tactical Mapping software; however, this procedure will not be addressed in this paper.

Cellular carriers derive geolocation information via two methods. The first method determines cellular phone location using a form of triangulation by measuring the difference in signal arrival times at different cellular towers (Hatfield, 2002). Other carriers digitally query the handheld device to provide coordinates from derived from an integrated GPS receiver (Hatfield, 2002). The accuracy of cellular phone searches vary based on the location method used and technological capabilities of both the cellular tower and handheld device. Federal wireless 911 requirements mandate cellular phone location reporting accuracy between 50 and 300 meters, however, GPS-equipped phones can report location accurate to nearly 10 meters (Di Justo, 2009).

In rare cases, forensic analysts are able to make active contact with the target cellular phone via voice or text message. In these cases, analysts advise victims to call 911, as the 911 system is capable of automatically determining the location of wireless callers much more rapidly than forensic methods.

Several factors affect cellular forensic searches. Analysts emphasize that forensic data can only be generated when a phone is powered on and connected to the cellular phone network. Forensic information is generated when a phone is used to make phone calls, transmit text messages, and access cellular data. Certain phones only provide forensic data when actively used for phone calls. In addition to the above

examples, cellular phones generate a forensic signature as they are automatically handed off between servicing towers. Any disruption in connectivity between the device and the cellular network can adversely impact the quantity and usefulness of forensic data. Cellular forensic searches are unusable if the target phone is turned off or switched to a non-transmitting mode, such as airplane mode. Additionally, mountainous terrain or other obstructions can disrupt the phone's connectivity with cellular towers, thus preventing the receipt of useful forensic data. Cellular forensic searches are also ineffective in particularly remote areas where the presence of cellular towers is sparse or non-existent. Cellular forensic methods are most effective in areas of flat terrain, not overly distant from population centers or transportation corridors, where the vast majority of cell phone tower coverage is concentrated.

Wireless-Enhanced 911

Modern 911 systems are capable of automatically determining the location of landline callers through an enhancement known as Enhanced 911 (Hatfield, 2002). As the number of emergency calls received from wireless phones grew, it became apparent that a mechanism similar to Enhanced 911 was needed to determine location information for cellular callers. Codified in the 1999 Wireless Communications and Public Safety Act, regulations were enacted to create a system to provide geolocation information for emergency callers (Hatfield, 2002). When calling 911, an automated process assigns the wireless caller a pseudo phone number that is associated with the cellular tower's directional antenna receiving the caller's signal (Hatfield, 2002). A series of automated processes compares the cellular caller's location with established jurisdictional boundaries, and routes the call to the appropriate emergency call center (Hatfield, 2002). The cellular carrier's Mobile Positioning Center digitally transmits the phone's callback number and location to the 911 system's Automatic Location Information database used at the emergency call center (Hatfield, 2002).

Cellular Carriage Regulations

Regulations complicate the use of cellular phone forensic information for aviation search and rescue applications. The carriage and use of cell phones is regulated by both the Federal Aviation Administration and Federal Communications Commission.

Codified in FAA-AC 91-21.1A, the FAA placed limits on the in-flight use of personal electronic devices (PEDs), with specific prohibitions against the use of cellular phones and other transmitting devices (FAA, 2006). These rules were originally implemented to avoid PEDs causing in-flight interference with aircraft navigation and

communications systems (FAA, 2006). A recent review of the issue resulted in the FAA relaxing PED restrictions and subsequently canceling the advisory circular. Based on 14 CFR 91.21, FAA regulations delegate the authority for determining PED interference and usage to the operator or pilot in command of the aircraft ("Electronic," 2014, Portable Electronic Devices, para. 1).

The FCC specifically prohibits the airborne use of cellular phones based on 47 CFR 22.925, which states that "when any aircraft leaves the ground, all cellular phones must be turned off" ("Electronic," 2014, Prohibition on Airborne Operation of Cellular Phones, para. 1). Similar to the FAA restriction, this regulation was implemented largely to prevent airborne cellular operation from interfering with other communications processes, particularly those in the 800 MHz band (Federal Communications Commission, n.d.). The agency is currently considering relaxing airborne operation restrictions on cellular phones. This proposed rulemaking policy adjustment is currently in the public comment process (FCC, 2014).

The relaxing of regulations pertaining to the in-flight activation of cellular phones could greatly enhance the availability of useful data to forensic experts when performing aviation search and rescue operations.

Commercial and Emerging Search Technologies

In addition to the aforementioned aviation search and rescue technologies, several emerging commercial systems have also been fielded to respond to aviation distress events. Known collectively as Satellite Emergency Notification Devices (SEND), these systems integrate digital satellite tracking and relay capabilities into portable, handheld devices for emergency alerting and messaging (Shay, 2012). Globalstar's SPOT Connect system features a palm-sized device connected via Bluetooth to a smart phone, which serves as the user interface (Bennett, 2012). The system provides one-way communications capability with location geotagging using the Globalstar satellite network, allowing the user to send text-style messages to family, friends, or co-workers. As of 2007, Globalstar sold more than 300,000 SPOT devices, of which the system has been credited with more than 1,850 rescues in more than 102 countries. Another satellite based system dubbed "Spidertracks" integrates technology from GPS, the Iridium Satellite Network, and Google Maps into a small device installed inside the aircraft (Lee, 2012). The Spidertracks system automatically reports the aircraft's location at two-minute intervals. Spidertracks automatically notifies selected individuals in the event connectivity is lost for more than three reporting cycles or six minutes. Alternatively, the pilot can manually send a distress signal from a push-button on the device. The Spidertracks device also allows Bluetooth, two-way text messaging connectivity via a smart phone application. DeLorme inReach is a mobile variant of the technology that

includes similar tracking, reporting, communication, and interface capabilities as the Spidertracks system (Shay, 2012). While not as robust as either SPOT or Spidertracks, the U.S. Forest Service's Automated Flight Following (AFF) system offers similar tracking capabilities, providing automated aircraft route recording and reporting via satellite at 2-minute intervals (Roth, 2012). Unlike SPOT and Spidertracks, the AFF system lacks user messaging capability. Although not specifically designed for search and rescue purposes, satellite phones offer yet another link to rescuers. Some satellite phone models incorporate embedded geotagging and SOS functions (Shay, 2012). While not specifically addressed in this paper, the efficacy of these emerging search technologies warrants further study.

Research Methodology

This study posed two research questions:

1. Does the use of Cellular Phone Forensics affect search duration?
2. Does the use of Radar Forensics affect search duration?

While not the primary means of locating distressed crewmembers following an aircraft crash, radar and cellular forensic methods are becoming much more prevalent search mechanisms following the COSPAS-SARSAT cessation of 121.5 MHz satellite monitoring. The study sought to quantitatively determine the individual contributions of these forensic methods in accelerating the search process for crashed aircraft.

The following hypotheses were established to answer the research questions:

H₁₀: There is no significant difference in search durations of aircraft searches that employ cellular phone forensics.

H₁₁: There is a significant difference in search durations of aircraft searches that employ cellular phone forensics.

H₂₀: There is no significant difference in search durations of aircraft searches that employ radar forensics.

H₂₁: There is a significant difference in search durations of aircraft searches that employ radar forensics.

This research was performed as a quantitative assessment of a historical census of search and rescue missions conducted by the Air Force Rescue Coordination Center from 2006 to 2011. The scope of the study was limited to general aviation aircraft in accidents occurring over land in the contiguous United States. Oklahoma State University granted an Institutional Review Board exemption for this study on October 4, 2012. Data for this study was obtained via Freedom of Information Act request [Case #2013-01258-F] submitted to the Air Force Rescue Coordination Center on December 12, 2012.

This study was conducted in concert with other varied research topics in the search and rescue process. The

received data included search and rescue mission information from the following categories: ELT type, cellular phone forensics, radar forensics, and mission duration reported incrementally in tenths of hours. Cellular and radar forensic information was limited to an affirmative or negative indication of whether those individual procedures were used during the course of the mission. ELT type information is not germane to this paper, thus will not be explained further.

The dataset of cellular and radar forensics information was binary coded based on the use of each respective forensic process. Data was initially evaluated using a General Linear Model for SPSS (GLM). To effectively use the GLM statistical tool, four conditions had to be met:

1. Independent Observations
2. Dependent Variable Scale of Interval or Higher
3. Normal Distributions
4. Distribution Homogeneity

The study design met the requirements of the GLM conditions for independent observations, since each search and rescue mission was conducted independently. Additionally, the dependent variable of search duration was measured in ratio scale, exceeding the interval scale requirement. Normality was tested using a Shapiro-Wilk Normality Test, with an established significance threshold of $p \leq 0.05$. If data was found to not meet normality requirements, a statistical transformation procedure was employed to improve normality. When used, transformed data was retested using the Shapiro-Wilk Test. Homogeneity was measured using a Levene Test, also with a significance threshold of $p \leq 0.05$.

If any subset of the dataset failed to meet all GLM requirements, the GLM method could not be used. If individual subsets met independence, normality, and homogeneity requirements, the data was retested using an ANOVA test. If data did not meet ANOVA requirements, the Brown-Forsythe F-Test of Equality of Means was used. The alternative Brown-Forsythe test was specifically selected because of its robustness to unequal samples sizes, non-normal distributions, and variance heterogeneity ("Univariate," n.d.).

Limitations

This study did not account for the following factors:

1. Search factors influenced by geographic location, topography, signal shielding or other factors that factors that may have degraded radar or cellular signal reception.
2. Variability in radar or cellular phone forensic methodology.
3. Activation, deployment, weather, logistics, or other delays affecting search and rescue operations or assets.
4. Delays encountered in the acquisition or analysis of radar or cellular phone forensic information.

Table 1
Forensic methods used among general aviation search missions from 2006–2011.

Year	No Cell Forensics	Cell Forensics	No Radar Forensics	Radar Forensics	Total Missions
2006	88	9	49	48	97
2007	75	9	36	48	84
2008	49	18	32	35	67
2009	10	19	4	25	29
2010	17	27	8	36	44
2011	22	22	15	29	44

Caveats

The researcher imposed the following scope limitations to control study validity:

1. Only overland missions occurring in the contiguous United States were assessed to control for the variability caused by diverse search and rescue organizational influences and varying search medium factors (i.e., oceanic vs. overland searches).
2. Missions were only included in the study if the target objective was positively located.

Results

The collected dataset contained mission data for ($N = 365$) individual search and rescue missions conducted between 2006 and 2011. Annual distribution of mission data is contained in Table 1.

The distribution of the dependent variable of mission duration produced a positive (right) skewed, non-normal, unimodal distribution (see Figure 1).

The visual histogram showed a clearly non-normal distribution. This observation was confirmed using the Shapiro-Wilk Test, which yielded a significance of $p < 0.001$, a non-normal finding.

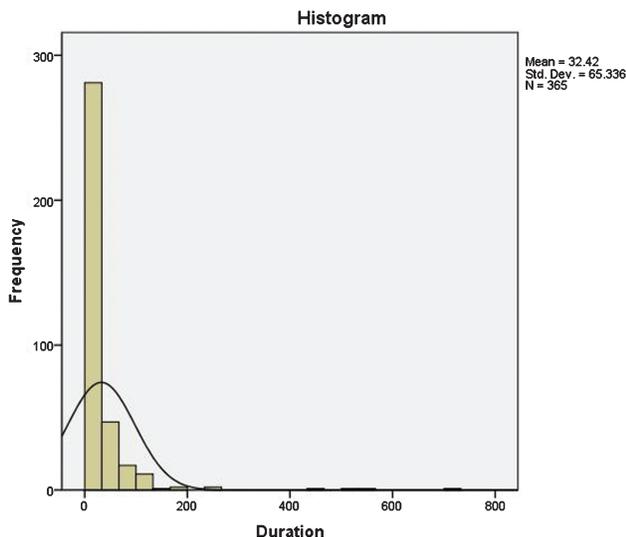


Figure 1. Displays highly-right skew distribution of mission durations.

To meet the requirements to use the GLM, the data was transformed to generate a nearly-normal distribution using a logarithmic transformation algorithm. The data results were retransformed back to hours to report useful information (see Figure 2).

A retest of the transformed data using Shapiro-Wilk resulted in a significance of $p = 0.059$, suggesting normality. This is further evidenced visually in a Q-Q Plot of the dependent variable in Figure 3. This result met the third requirement to use the GLM.

The data was finally tested for homogeneity using the Levene Test, yielding the results reported in Table 2.

The Levene Test yielded significant results for the Radar Forensics data, when compared against the established alpha level of $p \leq 0.05$. This finding indicated the data was not homogeneous, thus the GLM approach was abandoned.

Hypothesis Testing: Hypothesis 1

Since the data for data subset of cellular phone forensics met independence, normality, and homogeneity requirement (see Table 3), the ANOVA test was used to assess the cell phone data yielding the results contained in Table 4.

The ANOVA test yielded a significance of $p < 0.001$, exceeding the alpha value. This finding indicates a

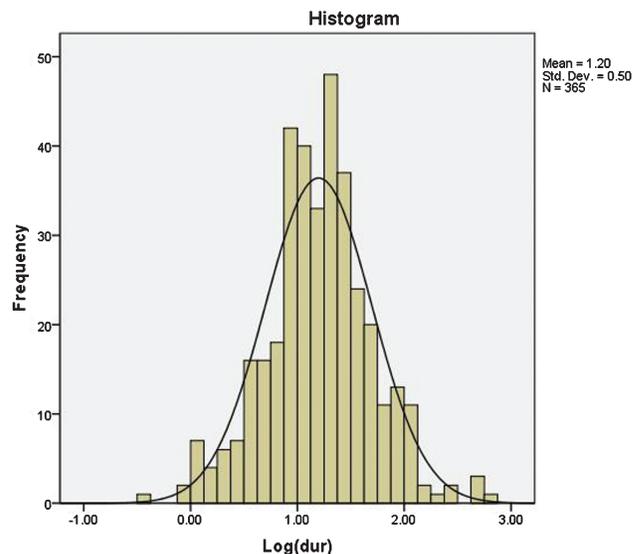


Figure 2. Following data transformation procedure, histogram is more characteristic of a normal distribution.

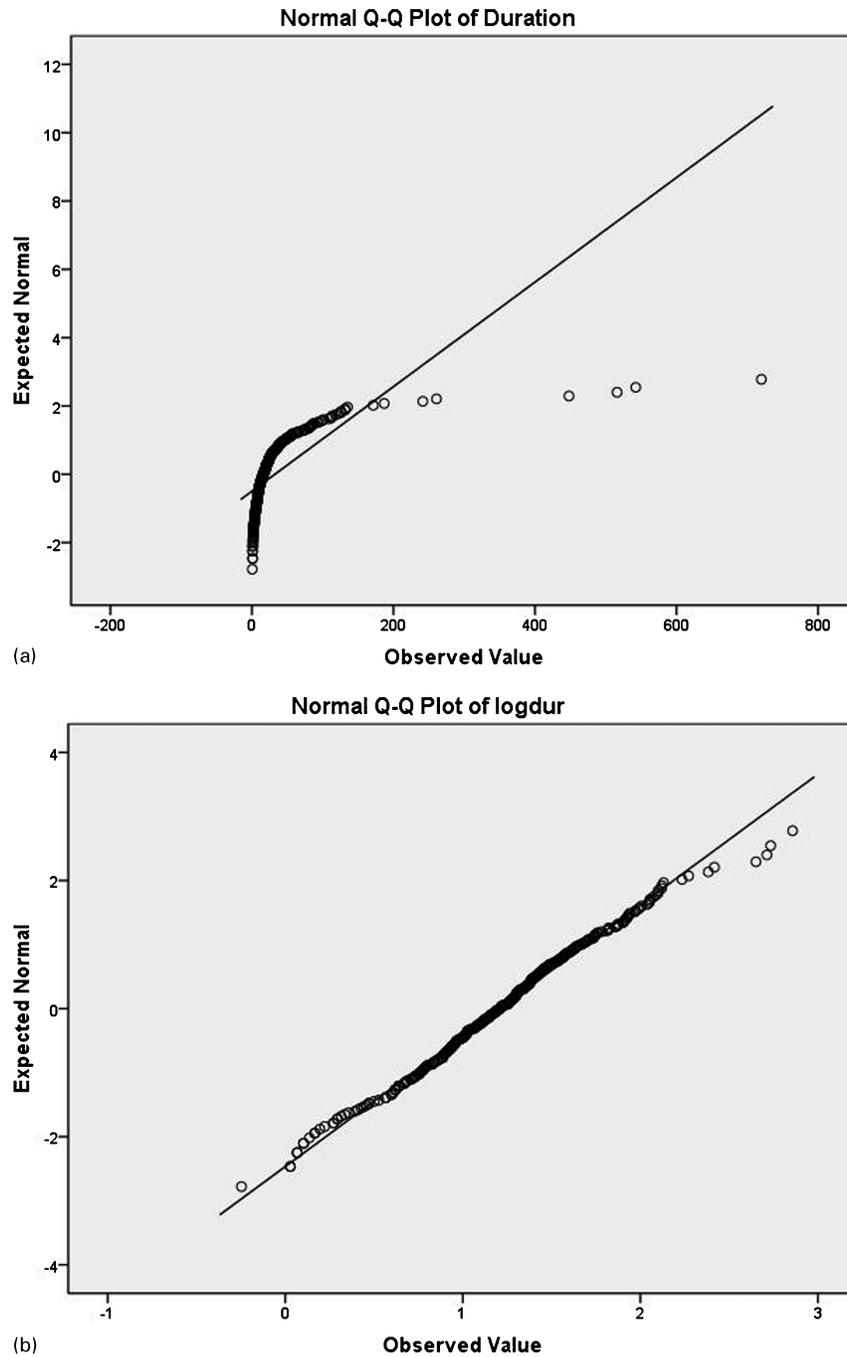


Figure 3. Comparison of Q-Q Normality Plots before and after data transformation. Expected normality is indicated by the solid, angular line. Data plots are those of the dependent variable.

rejection of research hypothesis 1 suggests there is a significant difference in search duration for aircraft searches which employ cellular phone forensics.

Table 2
Levene test for homogeneity of variance.

Category	Levene Statistic	df1	df2	Sig
Cellular Phone Forensics	1.266	1	363	.261
Radar Forensics	8.922	1	363	.003

Hypothesis Testing: Hypothesis 2

Since the data for radar forensics failed to meet homogeneity of variance requirements to use the ANOVA test (see Table 5), the alternative Brown-Forsythe F-Test was used yielding the results in Table 6.

The Brown-Forsythe Test resulted in a p-value of $p < 0.001$, suggesting a rejection of research hypothesis two indicating that there is a significant difference in the durations of aircraft searches that utilize radar forensic methods.

Table 3
Transformed descriptive statistics for cellular phone forensics use.

Statistic	No Cell Forensics	Cell Forensics	Total
N	261	104	365
M	1.1201(13.19)	1.36961(23.42)	1.1987
SD	0.49735(3.14)	0.45079(2.82)	0.49976
SE	0.03079(1.07)	0.04420(1.11)	0.02616
95% CI (L)	1.0595(11.47)	1.3085(20.35)	1.1473
95% CI (U)	1.1807(15.16)	1.4838 (30.46)	1.2502
Minimum	-0.40 (0.40)	0.00(1.00)	-0.40
Maximum	2.86(724.44)	2.71(512.86)	2.86

Note: Logarithmic values reconverted into duration hours represented in parentheses.

Table 4
ANOVA test of cellular phone forensics.

ANOVA	SS	df	Mean Square	F	Sig
Between Groups	5.667	1	5.667	24.133	<.001
Within Groups	85.244	363	.235		
Total	90.911	364			

Table 5
Descriptive statistics for radar forensics use.

Statistic	No Radar Forensics	Radar Forensics	Total
N	144	221	365
M	1.0001(10.00)	1.3282(21.29)	1.1987
SD	0.39406(2.48)	0.519291(3.31)	0.49976
SE	0.03284(1.08)	0.03493(1.08)	0.02616
95% CI (L)	0.9352(8.61)	1.2593(18.17)	1.1473
95% CI (U)	1.0651(11.62)	1.3970(24.95)	1.2502
Minimum	-0.40(0.40)	0.03(1.07)	-0.40
Maximum	2.12(131.83)	2.86(724.44)	2.86

Note: Logarithmic values reconverted into duration hours represented in parentheses.

Conclusions

The study's results show that missions employing either cellular phone or radar forensic search methods resulted in a significantly different search durations over missions which did not employ forensic methods. Interestingly, the descriptive statistics indicate that the use of forensic methods in search and rescue results in higher search durations than if those methods are not used. If cellular phone forensics were used, the mean mission duration was 23.4 hours versus only 13.2 hours for missions which did not use cellular forensics. Similarly, if radar forensics were used during a search mission, the mean mission duration was 21.3 hours versus 10.0 hours if radar forensics were not used.

Table 6
Brown-Forsythe test of equality of means for radar forensics.

Category	Brown-Forsythe Statistic	df1	df2	Sig
Radar Forensics	46.812	1	354.599	<.001

This revelation was counterintuitive since forensic methods were expected to add valuable information to the search and rescue process, thus giving searchers additional means to confine search operations. One possible explanation for this finding is that searchers may exhaust traditional aviation search methods, such as ELT detection, before employing alternative forensic search methods. Another possible explanation for the finding is that the analysis of the forensic data may require significant time to acquire and process for meaningful information. Since both of these factors were not assessed during the course of this study, they are merely speculative. Clearly, additional research is necessary to understand why the use of radar and cellular forensic methods resulted in elevated search durations.

Nevertheless, reliance on forensic search methods is increasing. As indicated in Table 1, the proportion of missions employing forensic search methods has increased from 2006 to 2011. With the cessation of COSPAS-SARSAT monitoring of 121.5 MHz ELTs, it is likely that forensic search methods will become increasingly important tools in locating crashed aircraft.

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