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Analysis of Pilot-Related Equipment and Archaeological Strategy in the Recovery of Aircrew Losses from the Vietnam War*

ABSTRACT: Determining the location and distribution of cockpit and aircrew-related equipment within the wider debris field of a military aircraft crash site is an essential first step in planning and executing the recovery of missing aircrew members presumed still to be on the site. Understanding the spatial relationship of these materials improves the likelihood of finding and recovering the remains of the aircrew during the excavation of an aircraft crash site. Since the greater portion of these unaccounted for crewmembers were involved in aircraft with single-seat cockpits or cockpits with two or three seats in tandem, pre-analysis of the debris pattern may be more-or-less straightforward. Larger, multiple-personnel aircraft, on the other hand, create a potentially more complex analytical situation given the aircrew's greater freedom of movement within the aircraft. Nevertheless, the same fundamental principles apply and, indeed, have been successfully so for some time in the civilian arena. But older aircraft crash sites, i.e., those dating to World War II, Korea, or the Vietnam conflict, have been and still are undergoing taphonomic processes that progressively alter these relationships. The following will illustrate that exchange of information between the anthropologist/archaeologist and the life-support analyst is required to maximize the effectiveness of field recovery and demonstrates the relationship between the recovery of life-support equipment and human remains and the effect that aircraft type has on this relationship.

KEYWORDS: forensic science, forensic anthropology, forensic archaeology, aircraft crash, life-support equipment, human remains, U.S. Army Central Identification Laboratory, Hawaii

The United States Army Central Identification Laboratory, Hawaii (USACILHI), regularly deploys search and recovery teams to Southeast Asia to recover the remains of U.S. service members who are unaccounted for as a result of the Vietnam War. The greater portion of the recovery operations conducted by the USACILHI in Southeast Asia involves the excavation of aircraft crash sites. This paper reviews the inferences that may be drawn from life-support and aircrew-related equipment in the decision-making process for recovering aircraft-associated losses. The objective of each excavation is to recover material evidence that will, to the fullest extent possible, contribute to case resolution. That material evidence, as it is recovered from the field, may be divided into eight hierarchically ordered categories as shown in Table 1.

This hierarchy of field data clearly presents a checklist for an ideal site situation. The first four of these categories also clearly include the entire site, since they focus on identifying the aircraft itself, though not exclusive of the final four steps. However, it is desirable to know as quickly as possible whether the recovery team has arrived at an A-6 Intruder crash site, for example, when they are searching for an F-4 Phantom crash site. This illustrates the necessarily incomplete overlap that exists between the first and last four classes of data. Specifically, while the successful recovery of sought-for personnel confirms both the site and aircraft, identifying the aircraft confirms only the site but not necessarily the status of the personnel.

During the Vietnam War, the American military utilized a variety of aircraft. Included in the aircraft inventory are three basic types: jet driven fixed-wing, propeller-driven fixed-wing aircraft, and helicopters or rotary-wing aircraft. Despite highly variable site conditions, the process of site formation always passes through three main stages, or transformations, each with their own peculiar variables. First is the crash event and its associated dynamics, including such factors as the type of aircraft, angle and velocity of impact, attitude (relative position of the aircraft) and structural integrity at impact, presence or absence of significant groundcover, and the resistance of the impacted substrate (2). For the occupants of the aircraft, this dynamic process exerts the initial traumatic forces, potentially extreme fragmentation and burning of the human body, that post-impact influences will act upon, further altering the integrity of the remains (3,4). Although dependent on the relative isolation of the crash site from populated areas, the second, immediate post-impact phase is most often characterized by direct cultural intervention (5). The third phase of site formation generally tends to be dominated by non-cultural environmental variables (6–17). Yet, even after decades, crash sites may still yield the necessary evidence for case resolution because all three of these site formation phases are comprehensible and amenable to systematic analysis. From the perspective of field archaeology, the only significant difference lies with the first phase, the actual crash and the immediately resulting debris field, which is not a site formation process typically encountered by the anthropologist/archaeologist. It is for this reason that the role of the life-support analyst is one of

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TABLE 1—*The hierarchy of physical evidence from aircraft crash site for achieving case resolution.*

1. Aircraft wreckage that confirms the type of aircraft involved, i.e., jet aircraft versus propeller-driven aircraft versus rotary-wing aircraft;
2. Aircraft wreckage that confirms the vehicle series, i.e., an A-1 Skyraider or an F-4 Phantom or a UH-1 "Huey;"
3. Aircraft wreckage that confirms the vehicle model, i.e., an F-4C Phantom versus an F-4D Phantom;
4. Aircraft wreckage that confirms the specific vehicle of record by its unique serial number;
5. Aircraft wreckage that isolates the cockpit portion of the debris field;
6. Cockpit debris and/or aircrew-related equipment that confirms the presence or absence of aircrew members in the crash site;
7. The presence or absence of personal effects potentially associated with individual aircrew members; and,
8. The presence or absence of human remains.

the most critical in providing assistance in identifying the evidence from the debris field of an aircraft crash site.

The recovery team, prior to deploying from the USACILHI, already has information concerning the incident. This information includes such pertinent details as the number of individuals unaccounted for, the aircraft involved, the location of the crash site, the results of witness interviews, and the results of the analysis of any material evidence that may have been recovered by the investigation/survey teams.

Armed with this information, the anthropologist/archaeologist and the life-support analyst, who has been trained in aircrew life-support and aircraft emergency egress systems, together with other members of the recovery team, conduct preliminary site reconnaissance. The purpose of this reconnaissance is to answer two essential questions, that of the site boundaries and to what extent a more detailed surface survey is needed to identify the cockpit portion of the debris field, and therefore the primary excavation area.

Once the provisional limits of the site are established and a preliminary metal-detector sweep is made to check for the possible presence of unexploded ordnance, a pedestrian surface search is conducted. Depending on the size of the site and the nature of the groundcover and terrain, this surface search may take the form of a skirmish line in a single sweep across the site, or the site may be divided into transects or quadrants to better record the distribution of material. A more detailed metal-detector sweep is also conducted at this time to identify the potential distribution of subsurface debris not apparent during the surface search. All metallic signals plus the visible aircraft wreckage, life-support, and other possible aircrew-related items are pin-flagged and mapped. Of particular importance to the life-support analyst are portions of aircraft emergency escape systems, aircrew flight apparel, and long-term survival equipment as listed in Table 2.

Given the previously listed variables for the initial phase of site formation (i.e., crash), the location and mapping of aircraft wreckage, life-support equipment, and other aircrew-related material to determine the probable crash pattern at the time of the incident is an essential first step in the recovery process. The larger and more dispersed the debris field is, the more important the data are, concerning differential distribution of life-support and aircrew-related items with respect to generic aircraft fragments, for the anthropologist/archaeologist, to determine the appropriate strategy and methods for excavation. The ability to make this strategic choice at the excavation site thus depends to some extent on the ability of the team (generally the Life-Support Analyst) to determine which non-biological components of the debris field are potentially related to life-support systems and/or to the aircrew themselves. Current policy and past practice by CILHI recovery teams has been to search and, if necessary, excavate crash sites in order to determine if life-support equipment and aircrew-related items, are present within the debris field. Subject to the location of life-support or aircrew-related items the entirety, including a substantial margin of that sub-portion of the overall debris field that is characterized by the presence of life-support equipment and aircrew-related items, is excavated to an incident sterile horizon. The data presented below review the results of the implementation of this strategy, considering the presence or absence of life-support or aircrew-related items, human remains and the type of aircraft involved.

TABLE 2—*Partial listing of critical life-support and other essential aircrew-related items.*

Aircraft escape:	Ejection seat components—lap belt, leg restraints, rocket motors; parachute components—canopy, cordage, risers, riser links, quick-releases, etc.;
Long-term survival:	Seat pack—inflatable life vest/raft, first-aid kit, signaling devices, survival knife, survival kit, escape-and-evasion map, issued sidearm, rations, etc; and,
Flight apparel:	Flight suit, flight boots, anti-gravity suit (G-suit), helmet, microphone, visor, torso harness, personal lowering devices, "blood chit," etc.

Methods

The remainder of this paper demonstrates the forensic value of locating life-support, cockpit, and aircrew-related equipment in an aircraft crash incident and its relationship to aircraft type. The identification and study of this material provide important clues to the possible location of remains during an archaeological excavation of an aircraft crash site. The location, identification, and study of these materials enable the anthropologist/archaeologist to develop an effective site recovery strategy, which in turn leads to the successful recovery of remains, and may provide answers on the fate of the aircrew. To date, anecdotal evidence (actual case experience learned by CILHI anthropologists) is more than sufficient to support this position. To assess this recovery pattern quantitatively, a Chi-Square (χ^2) statistical analysis was conducted of 142 crash site excavations conducted from January 1993 through October 1995.

Regardless of the type of aircraft, aircrew have life-support, survival, and escape systems that help them endure the rigors of flight and, in the case of an impending crash, to escape from the aircraft and to survive on the ground until rescue. The following analysis statistically compares the number of cases where life-support and human remains leading to resolution of aircrew fate were recovered to those cases where no substantive evidence was recovered. These data are detailed in Table 3 listing of observed (O) and expected frequency (E). Given these data, the Null Hypothesis 1 (N_1) is that the occurrence of life-support equipment and recovery of human remains in a crash site are independent of one another. The Alternative Hypothesis 1 (A_1) is that there is a significant relationship between these two variables, specifically that they occur more frequently together than expected due to chance. Since these are nominal data, a Chi-Square Test (18) is used.

The four possible combinations of the presence or absence of life-support equipment and human remains are used to organize the data. Table 3 compares observed and expected frequencies and presents the result of the Chi Square analysis for this and subsequent analyses.

Another question that should be asked of these data is whether the strength of association between life-support equipment and hu-

TABLE 3—*Presence or absence of life-support equipment and human remains and presence or absence of human remains by vehicle of loss where life-support was recovered.*

Hypothesis 1	+*LSE*		−*LSE*	Totals
+*HR* *OBS/ESP*	77/61.18		0/15.70	77
−*HR* *OBS/EXP*	36/51.59		29/13.23	65
Totals	113		29	142
			$\chi^2 = 43.2$, *p* value = 0.000, 1df	
Hypothesis 2	+*LSE* +*HR*	+*LSE* −*HR*	Totals	
Jet				
OBS/EXP	32/38.84	25/18.15	57	
Propeller				
OBS/EXP	32/27.93	9/13.06	41	
Helicopter				
OBS/EXP	13/10.22	2/4.77	15	
Totals	77	36	113	
			$\chi^2 = 8.0$, *p* value = 0.018, 2df	
Hypothesis 2.1 (fast vs. slow movers)			$\chi^2 = 7.6$, *p* value = 0.005, 2df	
Hypothesis 2.2 (fixed wing versus helicopters)			$\chi^2 = 5.8$, *p* value = 0.02, 1df	
Hypothesis 2.3 (fixed wing propeller driven vs. helicopter)			$\chi^2 = 0.5$, *p* value = 0.47, 1df	

man remains is independent of the type of aircraft. At face value, it might be expected there would be a greater chance of recovering human remains together with life-support equipment from crash sites involving helicopters and other propeller-driven aircraft than from crash sites involving jet aircraft, considering the greater speeds at which jet aircraft fly, their higher impact velocities, acute crash attitudes, and the consequent extreme fragmentation of the human body. Yet, contrary to these expectations, recovery teams successfully recovered human remains from over half the jet aircraft crash sites at which life-support equipment was recovered (Table 3). There are several potential reasons why jet crashes still result in remains recovery. Amongst these are the enhanced survivability of life-support and other aircrew-related equipment (through the development of fire-resistant materials and superior construction of components) coupled with the close association of this hardy equipment with the aircrew. This permits the anthropologist/archaeologist recovering the site to target the relevant part of the total debris field, facilitating the location of biological remains that might otherwise be impossible or impractical to locate. Another consideration is "salvage behavior." For example, considerably less easily salvageable material remains after a jet aircraft crashes compared to slower moving (lower impact velocity) aircraft. Thus, while jet-aircraft crash debris fields are not ignored by salvagers, there is a greater likelihood that a greater portion of these will be overlooked because the metal items are too fragmented and the recovery effort for deeply buried and widely scattered component is too great.

The other aspect concerning recoverability of human remains and life-support and the aircraft type has to do more with the function of the aircraft and therefore its configuration rather than with its power plant. Specifically, some aircraft are designed such that once seated in the aircraft the aircrew remains seated until they exit the aircraft. Generally these are single-seat or two-seat attack aircraft, which are predominantly jets, although small fixed-wing and rotary-wing aircraft fall into this category as well. In contrast to this group are those aircraft in which the aircrew has varying degrees of mobility within the plane while it is in flight. This fundamental difference means that in the first instance the aircrew members will necessarily be tethered to their life-support gear while in the second case, they will not. For example, on larger multi-engine aircraft like the C-130 Hercules, safety helmets, parachutes, and other such items are often set aside, accessible but not necessarily being worn by all members of the aircrew. In addition to this there is the problem of possible redundancy of life-support equipment reflecting more individuals than actually aboard the aircraft, as well as the opposite consideration of extra personnel not listed on the manifest of a lost aircraft. With smaller aircraft, many of the life-support components are physically part of the aircrew's seating; there is no option. As a result, although both life-support equipment and human remains may be present in a large aircraft crash site, there is the possibility when locating and excavating a life-support debris field that it may not actually circumscribe the location of the human remains, though both may be present at the crash site. This then would tend to diminish the association of life-support equipment and aircrew remains in a crash site for aircraft such as propeller driven fixed-wing aircraft and helicopters where direct physical association of life-support equipment and the body of the aircrew member in flight is not a functional constraint of the aircraft configuration.

The Null Hypothesis 2 (N_2) in this case is that type of aircraft has no bearing on the relationship between occurrence of human remains and the occurrence of life-support equipment. The Alternative Hypothesis (A_2) holds that there is a significant association between the occurrence of human remains, given the recovery of life-support equipment in a crash site, and the type of aircraft involved. Hypothesis 2 can be further specified by an analysis of fast versus slow moving aircraft (jet fixed-wing versus propeller fixed-wing and helicopters) that is here termed Hypothesis 2.1, and fixed-wing versus rotary aircraft (jet and propeller fixed-wing versus helicopter) here termed Hypothesis 2.2. Finally, Hypothesis 2.3 tests the association of human remains and life-support equipment within the slow moving category contrasting the data observed for propeller driven fixed-wing craft versus helicopters. In each case the null hypothesis is that within the population of crash sites yielding life-support equipment, the distribution of cases in which human remains are recovered is random with respect to aircraft type.

Results

The χ^2 value for the data illustrating the presence or absence of human remains and life-support equipment in Table 3 is 43.2, with a p value of 0.000 [18]). One may therefore reject the Null Hypothesis (N_1) of independence between the variables of life-support equipment and human remains and accept the Alternative Hypothesis (A_1). There is a significant association between the occurrence of life-support equipment to human remains. Although this finding is not unexpected, the empirical demonstration of the strength of this association is noteworthy. The results of the χ^2 analysis of these data, examined in the context of the type of aircraft crash site excavated are not as immediately intuitive. The calculated χ^2 value of 8.0 with a p value .018 [18]), one may reject the Null Hypothesis (N_2) of independence between the co-occurrence of human remains with life-support equipment and the type of aircraft involved and accept the Alternative Hypothesis (A_2). There is a significant association between co-occurrence (of human remains and life-support equipment) and the type of aircraft crash site excavated.

Despite the fact that the association between life-support equipment and the body of the aircrew member is more extensive in flight, it does appear that given the recovery of life-support equipment in a crash site, human remains are still significantly less likely to be recovered from jet aircraft than from other aircraft. When this is further analyzed under Hypothesis 2.1 it is evident that slow moving aircraft crash sites were associated with significantly greater numbers of recoveries of human remains ($\chi^2 = 7.6$, $p = 0.006$, 1 df). To test the possibility that this effect is inflated by the inclusion of helicopter crash sites in the slow mover category, Hypothesis 2.2 used exactly the same data to test the association of human remains recovery in life-support equipment contexts for fixed-wing aircraft versus helicopters. In this case $\chi^2 = 5.8$, ($p = 0.02$, 1 df). Finally within the 56 crash sites of slow moving aircraft, the association of remains recovery with aircraft type was compared for fixed-wing versus helicopters. Here $\chi^2 = 0.5$, ($p = 0.47$, 1 df).

Discussion

The results of this survey strongly suggest that when life-support or aircrew-related equipment is recovered, then the probability is good that remains will also be recovered, provided perimortem and post-mortem taphonomic processes have not so totally transformed the remains as to be non-recoverable. Both force dynamics and taphonomic processes must both be considered to ensure a successful excavation strategy. When life-support and aircrew-related equipment are located and recovered from Southeast Asia the probability is increased that human remains will be recovered. If human remains are not recovered, then the life-support, aircrew and cockpit-related equipment, if found and recovered, can be analyzed by life-support specialists in the United States. The results of such analysis may provide circumstantial evidence on whether the aircrew member(s) were in the aircraft at impact and whether the incident was survivable. This can provide information that can be helpful in the case resolution of the incident and the probable fate of the unaccounted-for service member(s). In addition to the quantitative strength of the association of life-support equipment and human remains, it is qualitatively noteworthy that in the 142 aircraft crash sites, there was not a single instance of human remains recovery where life-support equipment was not found at the crash site.

Despite the lack of concrete physical association of much of the life-support equipment with the aircrew in slow moving aircraft during flight, there is a significantly greater association between the recovery of life-support equipment and human remains in slow moving aircraft than in fast moving jets. Although a parallel analysis of fixed-wing and helicopter crashes also shows a significant association of human remains recovery and aircraft type, the strength of this association is weaker. This supports the idea that it is the speed of the jet aircraft that mitigates against the recovery of human remains in contexts where life-support is present rather than the configuration of the lift surfaces. This is further supported by the analysis of the slow movers themselves (Hypothesis 2.3) where there was no clear association between aircraft type and remains recovery when just helicopter and slow moving fixed wing aircraft were considered. Although the association of equipment and aircrew in flight is less rigid in slow moving aircraft, the association of recoverable human remains with life-support equipment is actually stronger than in fast moving jet aircraft. Although the field of aircraft crash site recovery is not amenable to experimental treatment, given the strength of the association demonstrated for all aircraft categories, we maintain that the data presented here offer quantitative support for CILHI's recovery strategies. The characterization of wreckage components as possible/probably life-support or aircrew-related equipment by a life support analyst at the excavation site and the characterization of the spatial distribution of such components by archaeological techniques are critical components of effective and efficient crash site excavation. In closing, we underscore that detailed analysis of crash debris, or what may be thought of as the "inorganic component" of an incident, does not guarantee successful recovery of the "organic component" of that incident. Nevertheless, the foregoing demonstrates that the methodological integration of air crash analysis with standard archaeological techniques does reasonably ensure case resolution if not full recovery of organic remains.

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