Document Title: Enhancing Scene Processing Protocols to Improve Victim Identification and Field Detection of Human Remains in Mass Fatality Scenes

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ABSTRACT

Considerable lessons have been learned in the aftermath of the terrorist attacks on the United States on September 11, 2001. Disaster management plans have been created adressing diverse issues such as pre-incident planning for first responders, forensic identification of the victims, or the need to keep victim's families informed. However, the field processing of the mass fatality scene has received less attention. A position paper by Homeland Security (*National Preparedness Guidelines*, September 2007) provides two important directives for this task: 1) all of the human remains must be recovered from the scene, and 2) this must be accompanied of the complete documentation of the human remains and all other evidentiary items.

The sheer volume of material present at the mass fatality scene often overwhelms investigators, who then tend to minimize the importance of proper and detailed documentation of the spatial distribution of the remains. It is assumed that the information to be gleaned by expending time and effort in the precise documentation of the location of items at the scene is negligible, and time costs for such effort are appreciable. The emphasis is instead placed on removing the evidence as quickly as possible, with little or no provenience (precise spatial location) documentation, in order to begin the process of identifying the victims, determining the cause of the crash and clearing the scene of all crash debris as soon as possible.

The field documentation and recovery of physical evidence associated with mass fatality scenes is indeed a tremendously complicated task. This is due to three interrelated factors: 1) the sheer volume of fragmented, and often comingled, human remains and other physical evidence, densely concentrated and anisotropically distributed at the scene, 2) the large size of the debris field created, and 3) the accordingly large number of personnel, equipment and other resources required to process the scene.

The current study addresses these problems by building on previous research and experience by the principal investigator. The primary purpose of the project was to significantly improve the efficiency and effectiveness of forensic "processing" (location, documentation, and recovery) of large-scale crime scenes, and specifically those resulting from mass fatality incidents. This was accomplished through testing, refinement, and validation of three research components: 1) technological protocol configuration, validation and budgetary cost assessment, 2) testing the efficiency of the new technological configurations of the *Weldon Spring Protocols* in terms of time and personnel costs, and 3) their efficacy in terms of recovery rates.

The improvements in scene processing were accomplished through the development and dissemination of enhanced, realistic, effective and affordable search and recovery protocols that maximize the detection, recovery, documentation and identification of human remains in mass fatality events. Important provenience data were acquired in a standardized manner that has benefits to real time recovery efforts, as well as to reconstructing past events related to manner of crash or bomb incident. The applicability of these enhanced protocols to a variety of other outdoor crime scenes was also addressed.

Comprehensive user-friendly protocols were developed based on mock bomb scenes and a real confined crash scene in Clarence Center, NY. The protocols include a description and explanation of pre-planning and procedures following the incident, including meetings for planning the response and recovery, and a description of the responsibilities of personnel involved. Following this description, two sets of protocols detail the preparation and considerations for establishing a recovery plan for scene documentation and victim recovery for a dispersed crash site and a condensed crash site. Organized by teams (photography, excavation, written documentation, etc.), the protocols go through the process, step by step, of how to carry out the search for, recovery, and documentation of victims of mass disaster scenes.

The results of extensive field testing indicated that comprehensive documentation of the spatial location of evidence and human remains can be accomplished in a time efficient manner with an increase in the recognition and location of evidence and human remains at a scene and therefore potential victim identification, while maintaining reasonable cost and working times.

Results also showed that accurate estimates of the volume of evidence could be made using plot and plotless search methods. These methods can be used to estimate the amount of evidence in unsearched areas as well as estimating the amount of evidence in the overall scene, thereby helping to predict needs assessments for personnel and the amount of time it will take to process and release specific portions of a scene.

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EXECUTIVE SUMMARY

Chapter I

Introduction

Statement of Problem

Disaster management plans have been created for municipal, state and federal agencies and deal with issues as diverse as pre-incident planning for first responders, forensic identification of victims, and addressing families of victims' issues. However, one area that is incompletely addressed is how to properly "process" the mass fatality scene. A recent position paper by Homeland Security (*National Preparedness Guidelines*, September 2007) provides two important directives: 1) all of the human remains are to be recovered from the scene, and 2) "complete documentation and recovery of human remains and items of evidence" must be completed. These directives also stress that mass disaster scenes are to be considered crime scenes and customary rules of evidence and chain of custody apply.

When faced with the prospect of "processing" a large-scale incident, the sheer volume of material present at the scene often overwhelms investigators, who then tend to minimize the importance of proper and detailed documentation of the spatial distribution of the remains. It is assumed that the information to be gained by expending time and effort in the precise documentation of the location of items at the scene is negligible, while the cost in time for such effort may be prohibitive.

However, the provenience of this evidence is important for a number of reasons: 1) it can be an important aid in victim identification, 2) it can provide evidence of the manner of crash, and 3) it constitutes physical evidence related to a potential crime scene, and therefore must be carefully documented *in situ,* in order to maintain prosecutorial significance.

The field documentation and recovery of physical evidence associated with mass fatality scenes, such as airplane crashes or bomb incidents, is indeed a tremendously complex undertaking. This is due to three interrelated factors: 1) the sheer volume of fragmented human remains and other physical evidence, densely concentrated and anisotropically distributed at the scene, 2) the large size of the debris field created, and 3) the accordingly large number of personnel, equipment and other resources required to process the scene.

A great deal of planning and logistic considerations is required in order for the process to be completed both *efficiently* and *effectively*. Consequently, well thought-out and detailed guidelines and protocols relevant to the processing of mass fatality scenes should be available to all groups responding to the incident.

The primary purpose of the project is to significantly improve the efficiency and effectiveness of forensic processing efforts at large-scale crime scenes, and specifically large scale mass fatality incidents. Improvements in scene processing have been accomplished through the development and dissemination of enhanced, realistic, effective, and affordable search and recovery documentation protocols that maximize the detection, recovery and identification of human remains at large scale scenes and have importance in reconstructing past events related to a plane crash, bomb incident or other related mass fatality scenes.

Review of Current Literature

The events of September 11, 2001 triggered a massive effort to improve disaster management planning at all government levels, resulting in a seemingly well-prepared government infrastructure and first response system (e.g., Alexander 2002, ASIS International 2003, Butler *et al.* 2003, Department of Homeland Security 2007, NIJ 2005, Stallings 2002). Homeland Security directives request “complete documentation and recovery of human remains and items of evidence” (Department of Homeland Security 2007, pp. 8), although no discernable guidelines or exact protocols is offered to accomplish this objective.

Large-scale forensic archaeology-based scene recovery protocols were initially formulated following the on-scene documentation of the physical evidence associated with the 1994 crash of USAir Flight 427 in Pittsburgh by members of Mercyhurst Archaeological Institute (MAI) (Dirkmaat and Quinn 1995; Dirkmaat and Adovasio 1997). This project served to demonstrate that comprehensive and efficient spatial documentation of evidence with a Total Station is possible within a reasonable time span at these types of scenes. Nearly 10,000 crash remains were precisely plotted without a significant increase in processing time (MAI 1994).

A more refined set of protocols was tested during a FBI training seminar (Dirkmaat *et al*. 2001, Reinecke and Hochrein 2008) carried out in Weldon Spring, MO. (For simplicity purposes, we refer to the resulting scene processing protocols as the *Weldon Spring Protocols*.) Four sequential, though concurrent steps are involved: 1) intensive and thorough search for and location of physical evidence, 2) total station data collection of three- dimensional spatial data and assignment of field specimen numbers, 3) photographic documentation, and 4) physical evidence collection, preservation, and removal from the scene. The *Weldon Spring Protocols*, far from resulting in increased recovery times, actually reduced processing time significantly, while increasing detection and recovery rates (Dirkmaat *et al.* 2001, Reinecke and Hochrein 2008).

Rationale for Research

The primary goal of this project was accomplished by conducting research relevant to: 1) enhancing and testing newly-configured documentation and recovery protocols to optimize the detection and recovery rates of physical evidence, while minimizing time, equipment and personnel costs, 2) producing user friendly and meaningful information technology protocols and tools to enhance data collection, sharing, integrity, and security at these scenes through the integration and testing of state-of-the-art (though, common) technologies, which dramatically reduce recording time, errors and duplication, and 3) scientifically testing the efficiency and effectiveness of the newly developed technology configurations.

The first component of the project requires the development and validation of two different technological configurations for the implementation of the *Weldon Spring Protocols*. These configurations represent the low- and high-end alternatives, in terms of costs and resources.

The second component involves testing the *efficiency* of the new technological configurations in terms of time and personnel required for their successful implementation.

The third component involves further testing of the technological configurations and resulting protocols in terms of *effectiveness*, measured relative to recovery rates. As a secondary output is field and statistical methods for the reliable assessment of the amount of evidence present at a given time at a particular scene area were produced.

Chapter II

Research Component 1: Protocol Configuration and Validation

Materials and Methods

The primary goals of *Research Component 1* were: 1) incorporating, configuring and validating recent technological advances for data collection (especially spatial data), enhancing detail and speeding up scene documentation while reducing human-induced errors in data collection and management, 2) expediting on-site data transmission and integration, which results in new and enhanced abilities to conduct on-site data analysis and offsite data sharing, 3) producing simple and meaningful guidelines and check lists for needs assessment and step-by-step technology configuration, aimed at law enforcement and first responders, and stressing the use of already available equipment, and 4) creating comprehensive but straightforward descriptions and training educational materials detailing each step of the recovery protocols, as well as their primary goals and objectives.

The principal investigator developed modifications to the basic recovery methodology, applicable to large-scale mass fatality scenes. As the needs and resources of each agency employing the recovery protocols will vary, two different technological configurations were developed and validated.

Data recording devices included electronic total stations, GPS units, digital photographic and video recording equipment, bar-coding equipment, and hand-held PDAs. A central computer performed data integration and analysis at the mobile command center. The key technological element of the *Weldon Spring Protocols* is the total station and survey-grade GPS unit, as recorders of precise and accurate three-dimensional location of items of evidence. Searches and the subsequent location of evidence were also enhanced, as was general onsite management, through the use of GPS data.

Personal digital assistant (PDA) computers were used to collect contextual data in the field. The corresponding databases were based on the ones previously developed for small-scale scene recoveries by the Department of Applied Forensic Sciences of Mercyhurst College (AFS Mercyhurst). A variety of software platforms and PDA models were evaluated, all with Bluetooth capability. The data recording databases, containing reference number, spatial coordinates, and media files related to field documentation, were designed to maximize their compatibility with current morgue operation databases. A bar coding system was used in the high-end configuration to label flags and recovery bags, reducing reference search and notation for the photography, recovery and morgue teams.

Following needs and resource assessment, each agency will be able to define its most feasible configuration (high or low-end). In most cases an intermediate solution between the proposed high and low end alternatives will be chosen.

Results

Technology Configurations

Handheld Computers

Examination and testing of handheld computers focused mainly on units with barcoding capabilities, as these are considered key for eliminating data ambiguities, reference duplications and recording errors. A number of different models of handheld computers have been examined based on their functionality, range of application (related to their amortization), and pricing.

Barcodes and Generating Programs

Several different code systems were researched and examined. CODE 128 is the optimal alternative for the protocols, particularly as it utilizes the full 128 ASCII character set. The alphanumeric set permits codes to contain both numbers and letters. It also displays text below the barcode for easy identification without a scanner. These can be customized on a case-by-case basis in order to maintain data organization and integrity.

Printers and Labels

Printers must support certain sized labels, and have a high enough resolution (greater than 200 dpi) in order to support the quality of the barcode necessary in the field. The configuration involving a regular printer in a rugged, foam padded case, represents a much more cost-effective strategy. Therefore, during needs assessment, budget allocation should favor better barcode scanners over more expensive printers if a budgetary decision between them is necessary.

Field Computers and Central Command Computer and Barcode Database

Most high end, ruggedized tablet PCs (such as MobileDemand XTablets of the T8700 and T8600 series) have been dismissed in the final configurations. They were deemed to be cost ineffective when compared with more conventional alternatives, such as the much cheaper Panasonic Toughbook series. The Trimble CU and TC Controller series have also been identified as optimal, cost effective alternatives for the initial collection, storage, and field transmission of total station and GPS data (Trimble R8). These devices are Microsoft Windows based (running on the Windows® CE.Net operating system), making them easily connectable to regular PC computers, at a competitive price.

Field Networking Systems

Alternative field networking systems have also been examined, with a special focus on security issues. Encryption and data protection protocols have been examined relative to three main alternatives: Bluetooth, 802.11 wireless or WiFi protocols, and Novatel MiFi Personal Hotspot.

Field Mapping Equipment

The Trimble R8 is a survey-grade GNSS (*Global Navigations Satellite System*) that combines total station accuracy with high-resolution GPS accuracy. As long as there are at least four satellites and a connection to the RTK network, the R8 is capable of georeferencing at subcentimeter accuracy. This effectively eliminates the need for a traditional GPS and total station. Three software packages were tested and foundefficient for coordinate data acquisition: *Evidence Recorder 5* was tested with the total station and *TerraSync* and *Survey Controller* were tested with the R8.

Scene Processing and Recovery Protocols

The investigators have produced user-friendly processing and recovery protocols for the mass disaster scene. The protocols include a description and explanation of pre-planning and procedures following the incident, including planning meetings, and a description of the personnel involved and the role of each group. Following this description the protocols detail the preparation and considerations for establishing a recovery plan for scene documentation and victim recovery.

The protocols then detail the excavation, documentation, and recovery protocols for a condensed crash scene. Organized by teams (photography, excavation, written documentation, etc.), the protocols go through the process, step by step, of how to carry out the search for, recovery, and documentation of victims of mass disaster scenes.

Additional information included in the developed protocols including: a number of photographs of the detailed step by step process; a description of the teams and their role in the recovery process (scene manager, photography, written documentation, videography, Total Station, search, excavation, collection, intake, debris removal, and screening); equipment needs and requirements; provenience number and provenience team configurations; examples of documentation and field forms; and a description and use of the Total Station.

Chapter III

Research Component 2: Efficiency Testing

Materials and Methods

The next step was to test whether these protocols could be implemented in a reasonable amount of time, with a reasonable number of responders. *Efficiency* was primarily measured in terms of *time required to complete all of the steps of the protocols*, under realistic conditions. This depends upon the spatial density of evidence observed at the scene, compared to the unit of area searched and personnel used. This component also provided feedback to *Component 1*, to further correct undetected technological configuration problems.

Feedback from independent observers taking part in the exercises provided necessary information for configuration and protocol validation and improvement. It also served for protocol dissemination. Finally, post-processing of the bomb scenes afforded essential data for *Research Component 3*. Work for *Research Component 2* consisted of the recovery and processing of an actual contained plane crash site in Clarence Center, NY, three mock bomb blast scenes, and three additional exercises in which technological configurations were tested and refined.

Original Research Design

The design was based on a series of previous field exercises, as well as on the basic design of the Missouri (*Weldon Spring Protocols*) exercise described in the original project proposal (Dirkmaat *et al.* 2001, Reinecke and Hochrein 2008). In these exercises, a vehicle was detonated, and the scene processed using the *Weldon Spring Protocols.* Protocol comparisons were made by processing identical areas of each exercise with the alternative configurations, and comparing processing times, as in the original Missouri (Weldon Spring) exercise.

In each exercise, 2 to 4 pigs were fully dressed and placed inside a vehicle, in locations replicating those typically occupied by humans in a vehicle. Each vehicle window was painted in different colors, using spray paint, allowing for the assignment of each glass fragment noted in the debris field to a particular location on the vehicle. Two pounds of *Kinepak* were then placed at different locations in the vehicle, under the vehicle, or on the animal model (as bomb vests), and detonated.

Once explosive specialists cleared the scene, an initial assessment of the scene was made and search crews were organized. The number of participants per exercise was between 20-30 individuals. In order to avoid pseudoreplication (Hurlbert 1984), the participants were randomly distributed into search teams for each search area and session. Randomizing the search crews, and using different crews each time, allowed for a simplified statistical analysis, as it made the different search and recovery efforts independent from one another. In this way, the average differences observed in protocol outputs cannot be attributed to team biases.

The scene area was divided into a number of parallel and adjacent corridors (approximately 10 x 30 m), and a recovery team processed each corridor. The search crews of each team were composed of 5-10 individuals, separated approximately 2 meters from each other in a line search. Corridor assignment was also randomized, and different searches were carried out concurrently. Exact corridor area, time for completion of each of the protocol steps, and number of items recovered (both total and per time unit) were recorded.

Plane Crash in Clarence Center, NY

At approximately 10:00 pm on February 12, 2009, Continental (Colgan) Flight 3407 crashed into a house in Clarence Center, NY. 49 passengers and crew on board and one individual on the ground were reported dead. The principal investigator was asked by the Erie County, New York, Medical Examiner's Office (ECME: Buffalo, NY) to lead the victim recovery effort at the scene. Dr. Dirkmaat and several members of the Applied Forensic Sciences Department at Mercyhurst College arrived in Buffalo just hours after the crash. Recovery efforts at the scene were conducted from February 13-16, 2009.

This scene represented a more contained crash area, as compared with the plane crashes upon which the *Weldon Spring Protocols* were constructed. In spite of the high degree of heat alteration and vehicle destruction observed, many of the victims (n=49) were more or less intact. A simplified but comprehensive alternative to the *Weldon Spring Protocols* was developed which can be applied in this type of confined crash scene. One the main scene documentation issues observed during the recovery was a lack of guidelines for total station procedures (not conducted by Mercyhurst DAFS personnel). Therefore, a set of standard, quick, and user-friendly total station guidelines were subsequently developed for these situations.

Post Bomb Blast Recovery Exercises

Efficiency testing was carried out during three post bomb blast recovery exercises that were conducted during the project period.

1. June 22-26, 2009: Wattsburg, PA

One of the major goals of this mock scene was to test the efficiency of the new technological configuration created in *Research Component 1* based on time and personnel costs. Apart from the complete processing of the scene, which allowed estimating overall scene parameters, two of the 10 x 30m corridors on each immediate side of the detonated vehicle were used to test the newly modified recovery protocols.

Corridor A was processed using the new technological configurations in their current state of development, using handheld computers and a barcode system, while the second corridor (Corridor B) was processed using total station and manual notation. The average time for completion of each component of the recovery effort was compared between the two corridors.

2. September 19, 2009: Williamsport, PA

All search corridors were processed using the bar-coding protocol adding the enhancements in database notation. One of the major goals of this mock scene was refining and testing the efficiency of the field protocols for total station data integration when multiple total stations are employed simultaneously. Additionally, an R8 GNSS (Global Navigation Satellite Systems) receiver was also tested with a tetherable cell phone (military grade) configuration.

When more than one total station was used to map the site, some important, rather time-consuming issues arose. Using the survey-grade GPS unit in conjunction with other instruments solved many, if not all of these problems. A single team member mapped a complete corridor in less than two hours, using the R8 for the first time. This time reduction also allowed the setting of two total stations almost immediately, so that all data taken during the exercise were immediately georeferenced with great accuracy. It was observed that the error rates obtained with the R8 are less than even those derived from the total station prism or the GPS pole.

3. June 23-25, 2010: Erie, PA

This exercise focused on the final testing of the wireless communication elements. The automobile detonation resulted in a fairly contained distribution of the evidence, covering approximately four search corridors. Line searches were carried out in all of these corridors, while the two more densely populated of them were documented and processed following the complete protocols.

The exact location of all evidentiary items was recorded with the R8 GNSS unit and tagging and documentation was carried out through the bar-coding system. Additional repeated line and plotless searches were carried out for *Component 3.* The exercise revealed a very steep learning curve for the protocols, with all participants being able to familiarize themselves, operate the equipment, and correctly apply all the steps of the protocols after a couple of hours of training and practice.

Other Exercises: Testing Equipment and Technology Configurations

Three additional exercises were used to test equipment and technological configurations. A number of mock fatal fire scenes were processed during field exercises for another NIJ funded grant awarded (*Award No. 2008-DN-BX-K131*). Investigators used these scenes to test and refine technology and technological configurations produced for this project. This allowed for a reduction in the amount of funds necessary to carry out equipment testing and refinement of configurations. During these exercises barcode configurations, documentation configurations, and data integration was tested and refined.

Results

Comparisons of each configuration have also served to assess the differences in performance between them, providing a baseline for cost and needs assessments. The relationship between recovery times and number of items recovered serve to improve scene management by better estimating the number of personnel required for a specific incidence. This improvement can be accomplished by providing straightforward estimates of the time required for scene processing (in real time) that depend on the spatial density of evidence observed at the scene. The parameter of time-per-item recovered will also serve to correct for scene difficulty during inter-scene (or inter-protocol) comparisons, as higher densities of evidence will require longer processing times.

Wattsburg, PA Bomb Exercise

Contrary to common belief, total stationing is the fastest of all the recovery tasks, other than the searches. In Corridor A (protocol including barcoding), 374 evidentiary items were mapped and catalogued in around 3 hours and 15 minutes of total station time, with an average time between 28 and 33 seconds (95% interval) per total station point, and a median of 28 sec. per point. 95% of the recovered elements required less than 55 seconds of total station time, and the element requiring the longest time to be recorded by the total station and handheld database only required slightly more than 4 minutes, though this was due to angle measurement errors on the theodolite that required recalibration before the point could be recorded.

These results stand in stark contrast with the general assumption that recording more than one point on each body is not feasible at a plane crash because of time constraints. The investigators calculated the projected total station times to process 1 to 100 victims, based on results in this research project. Depending on the degree of detail used to describe body positioning and location (i.e., taking either 5 or 13 points per victim). The obtained times, around 30 seconds per total station point, also provide a preliminary guideline to assess the desirable objectives to be attained during training for response to this type of scenario.

Two total stations with different software configurations (*Trimble* and *Evidence Recorder*) were employed in the exercise, in order to test and refine the protocols for data combination and sharing between two different total stations and software platforms. Each software configuration allows the user to export the spatial data into different file formats. Both of the formats can be integrated into a GIS (geographic information system) and combined. Preferably, each total station used should be over an established datum with known GPS coordinates. In this way, no post processing will be necessary to link the data. If the total stations are not geo-referenced, they must take at least 4 points in common to later link the data.

Finally, two plotless searches were performed in the two test corridors after the initial search, followed by successive line searches, intended to estimate the amount of evidence missed during the initial searches. These data suggest that initial recovery rates were very high in these close-to-real exercises.

The recovery times (efficacy) obtained for the protocols are essentially identical to those obtained in previously reported exercises, with average times of around 30 seconds per point in the recording phase, and the photographic documentation as the slowest phase, which is corrected when bar-coding and two photography teams per provenience (total station or R8) team are employed.

Williamsport, PA Bomb Exercise

A single team member mapped a complete corridor in less than two hours using the R8 for the first time. In this exercise, the other two total stations were erected over data geo-referenced with the R8, so that all data taken during the exercise were immediately geo-referenced. It was observed that the error rates obtained with the R8 are inferior to those derived from the placement of the tip of either the total station prism or the GPS pole (around 5 cm or higher).

The plot (capture-recapture) sampling exercises revealed a very high efficiency of the search protocols under the current experimental conditions, with recovery rates above 90% per single search in all cases, and often with 100% recovery rates. While these figures allow for a very optimistic protocol efficacy assessment when the realistic, mock bomb scenarios are considered, they may also suggest that evidence detection potential may be overestimated in the experimental conditions set for the Missouri-style exercises, resulting in potential biases toward density underestimation in the plotless, distance sampling equations.

The initial evidence density estimates obtained through plotless searches show central figures very close to the real values, apparently regardless of item sizes, as well as consistent decay lines with distance from the observer, at distances within four meters, in spite of obtaining high detection rates (on average above 70%, and in many cases above 90%). This actually seems to suggest that, as predicted by the distance method, the ease or difficulty to detect the items do not play a role or is biasing the results. However, the current sample (number of replicas) is still too small, providing confidence envelops way too wide to extract any reliable conclusions.

Erie, PA Bomb Exercise

The bomb blast exercise in Erie, PA revealed a very steep learning curve for the protocols, with all participants being able to familiarize themselves, operate the equipment, and correctly apply all the steps of the protocols after just a couple of hours of training and practice, particularly when the R8 GNSS substituted the total station. This was also confirmed by the feedback received from all participants.

Chapter IV

Research Component 3: Effectiveness Testing

Materials and Methods

The key measure of the “success” of a mass scene processing protocol is the rate of recovery of physical evidence. Recovery rates will depend primarily on the first step of the recovery protocols, namely search and location of evidence.

Direct counts of the evidentiary items recovered per unit time can serve to compare protocol configurations and modifications, assuming that the areas processed with each alternative protocol share similar evidence densities and distribution, the later including both size and spatial distributions. The recovery strategy and protocol configuration producing more items per unit time will be the more efficient one. However, the most efficient configuration may still not be effective enough in a real scenario. Recovering a large amount of evidence does not suffice if a comparatively large amount of human remains and evidentiary items still goes undetected.

Research Component 3 addressed these problems through: 1) the development and testing of reliable strategies and methods to estimate the amount of evidence present at the scene, and 2) the application of the developed search strategies and density estimates to the bomb drill scenes (described in *Research Component 2)*, to assess both their effectiveness and applicability in quasi-real conditions, and the recovery rates associated with each recovery protocol configuration.

Research Design and Methods

Data for this research component were collected from: 1) simplified Missouri-type scenes, with known evidence densities and homogeneous terrain characteristics, and 2) post-processing of the bomb drill scenes created in *Research Components 1* and *2*.

The research design for this component was based on exhaustively tested field ecology sampling methods, employed in the estimation of species abundances (Borchers *et al.* 2004, Buckland *et al.* 2001). These methods require the recordation of precise spatial coordinates of the evidence, or counts of evidentiary items per unit area, as well as the recordation and monitoring of the evidence recovered in successive searches.

For the first data source, simplified versions of the Missouri-style exercise (Dirkmaat *et al.* 2001, Reinecke and Hochrein 2008) were created at Mercyhurst College, on a smaller scale but with a much higher number of experimental replicas. Different search strategies were applied to obtain density estimates in a number of experimental search regions of known surface area and item density.

The mock evidentiary items consisted of series of porous concrete fragments of varying sizes, paint-coated to mimic the grassy terrain. The items were then numbered consecutively from 1 to 1800. After numbering, each item was weighed to the closest ±0.2 g, and all weights linked to the corresponding item number. Given that all the items are solid blocks of the same material, their weight provides a good estimate of their size, which is expected to strongly correlate with detectability. The weight distribution of the sample departs from normality (D'Agostino & Pearson omnibus normality test, $K_2 = 696.7$; $p<0.001$), with a long tail toward higher weights. While not affecting the calculations for the plot and plotless (distance) density methods (below), this skewed distribution, was preferred in order to prime difficult detection conditions to avoid over-estimation of recovery rates, while still considering a large size range of evidentiary elements, similar to that found at real scenes.

Three of these exercises were carried out at different locations in Erie, PA and Franklin Center, PA. A total of four rectangular 30x10m corridors were created (1 + 2 + 1), according to the general methods described in the project proposal. In the first two exercises (three search areas), 1500 mock items were quasi-randomly distributed across the search area. Assistants arbitrarily tossed a matching number of surveying flags along the search corridor. A mock evidentiary item was then placed at the tip point of each flag stem. The exact location and reference number of the evidentiary items were then recorded using the Total Station. As the items were mapped, the flags were removed. The corridor stakes, lane points and distance search lines were also mapped to establish a reference framework for searches and items.

For the third search exercise, the number of objects was reduced to 800. These densities were selected based on the ones observed in the bomb exercise in *Component 2* above (under 400 items per corridor in all cases), in order to match more realistic scenarios. A Trimble R8 GPS was used to collect the data.

Two different density estimation methods were then tested in these searches: *Plotless methods*, aimed at providing early density estimates before the areas are line-searched, and plot methods, based on the decreasing rates of materials detected as a particular area is line-searched multiple times.

Plotless Methods: Evidence Density before Scene Processing

Distance, Line-Transect sampling or, more generically, *plotless methods* (Buckland *et al.* 2001) are typically employed to estimate the density of moving animals or, more relevant to this study, inanimate objects. They allow the researcher to obtain reliable density estimates with minimum personnel and in a very rapid manner. Their parametric requirements also fit the conditions in mass disaster scenes. They do not assume that the items are randomly distributed within the search area, which is expected to be the case of a mass disaster scene, where evidence density decreases with distance to the focal point of impact or explosion. Finally, these methods allow for variability in the detection rates of the observers, as the estimates are not based on item counts (as in the plot methods described below), but rather on the distances of the detected objects from the reference line.

A useful property of this detection function is that it serves to correct both for the detection ability of a particular observer and for interobserver differences. Arguably, these methods are even more accurate than the exhaustive methods applied to search and process mass scenes, which are akin to the plot methods described below (Engeman and Sterner 2002).

Four parallel search lines were defined and marked with nylon string in each of the experimental areas. This design was simply intended to allow for several of these exercises to be carried out concurrently, without overlapping search areas, thus allowing for a larger number of replicas per exercise. Following preparation, a crew of students was familiarized with the general appearance of the mock evidentiary items, and each was asked to perform a distance search. The student walked through the corridor alongside the 30 m string looking for items. Assistants followed the searcher flagging all items identified by the first student. Another two students followed noting the number of the detected items, whose location had already been determined.

In this study, a total of 53 of these distance searches (13+26+14) were performed along 10 different corridor lines and carried out by more than a dozen different individuals.

Perpendicular distances to the search line were estimated from the total station or GPS point data in *ArcGIS*, and distance data were analyzed using the software *Distance* 6.0 (Thomas *et* *al.*, 2010.) Item densities were estimated through Variable Area Transect Methods (VATM), with bootstrapped confidence intervals (Buckland *et al.* 2001, Engeman and Sterner 2002, Engeman *et al.* 2005.)

Plot Methods: Assessing the Amount of Evidence remaining after Initial Scene Processing

Plot methods do not require the application of any new searching techniques, but rather keeping track of the evidence detected and removed in different areas as the recovery effort progresses. The idea behind plot methods is that the evidence left at the scene can be estimated as a function of the amount of evidence recovered in consecutive searches.

The methodology employed in this study is known as a *plot sampling removal method for density estimation* (Borchers *et al.* 2004). The Maximum Likelihood Estimator (MLE) for the two-search model can be easily generalized for a larger number of searches by substituting the equation-system. Application of the same method in real situations will hopefully allow for the assessment of not only the amount of evidence still present at the scene, but also its expected average size, an important factor when deciding whether the scene should be released (items under a given size range may be considered undetectable or unrecognizable as human remains or disaster trophies).

This study proposed testing different models, in particular *Change-in-Ratio* methods (Borchers 2004), with bootstrapped confidence intervals (Borchers 2004, Davison and Hinkley 2007, Manly 1997), which are considered to have high potential to estimate evidence density, recovery rates, time to completion of scene processing, or the optimal amount of personnel required to complete the recovery. However, as will be described below, the observed recovery rates were so high, both in mock bomb scenes or in the Missouri-style exercises that they would not allow for further comparisons or analyses pass the simplest model. However, due to their immense potential and ease of application in real situations, we kept their general theoretical outline and rationale description.

Recovery rates were assessed through this method for the three experimental corridors and two of the bomb exercises in the study. In this way, successive line searches, with crews of searchers advancing through the corridors shoulder to shoulder were repeated until detection rates approached zero. These searches were discontinued in further exercises, due to the extremely large recovery rates observed, which made any further calculations irrelevant.

Results

Plotless Methods: Estimating Evidence Density before Scene Processing

The exercises showed that distance sampling, having a single observer identifying objects while walking across predetermined straight lines can be accomplished in a quick, efficient manner, rendering reliable estimates of the amount of evidentiary items present at different areas of the scene. In the final exercise, after the distance search protocols were refined and definitively determined, and utilizing an R8 GPS unit, the average time to complete one of these searches was around half an hour (32 ± 7 minutes).

A lateral bias was generally present, with the searcher detecting more items at one of their sides. This asymmetry seems to be very correlated across observers and within search efforts and corridors, also switching from right to left in different corridors and exercises. This suggests that it may related with visibility conditions, depending on grass height, light angle, etc.

Individual differences in detection rates were present, but did not noticeably affect the detection probability functions obtained. Detection rates within the closest meters to the line were high in all cases. Detection within one meter of the line averaged 88.4% in the six corridors searched in *Exercises 1* and *2*, descending to 70% at four meters. Only three out of 30 searches detected slightly less than 70% of the items in these exercises, with four out of six trails averaging more than a 90% detection rate.

These detection rate figures are important first because they further confirm the efficiency of conventional forensic line searches, as the one-meter figure approximately corresponds to the arm-length distance recommended in those searches. Secondly, the high detection rates also indicate that effective search distances should not be fixed in less than two or three meters. The effective search distances estimated in *Exercise 3* were around five meters in all cases, suggesting a minimum recommended distance of 2.5 to 3.0 meters at each side of the central search line, when this is fixed by marking the search trail boundaries with string.

However, the consistency of the effective search area and density estimates obtained in the study suggests that in areas with low densities of evidence determining and marking the search corridor boundaries are unnecessary. Basically, the search team should decide on a per-case basis, based on the trade-off between the time necessary to measure and fix the string boundaries, and that may result from recording the amount of material present at longer distances.

When single individual searches were considered to produce the final density estimate, six out of the 14 searches, or 43% resulted in confidence intervals not containing the real number of items present at the scene (800 items for an average density of 2.67 items/m^2). This figure is actually not significantly different from the 0% probability of random chance. However, only two of the individual searches resulted in gross underestimates (more than 100 items less than actually present at the scene) when the upper confidence limits are considered, with all of them rendering maximum estimates of 630 elements or more. This extreme is particularly relevant, as the main concern in a real situation would be grossly underestimating the amount of evidence present in a section of the scene.

From a practical point of view, this results in the recommendation to perform at least three or four searches in each area, by the same observer and along search lines randomly placed following different orientations, whenever possible. Then again, we must remember that the data from each individual search can already serve to provide a good assessment “on the go,” if they can be transmitted or processed directly at the scene as new searches are being performed. Areas with low densities, such as those at the outer limits of the general scene, or which are being surveyed in order to decide their potential release, would probably require a minimum of four of these searches, depending on time availability and the topography of the area.

Plot Methods: Amount of Evidence remaining after Initial Scene Processing

Density estimates through plot methods were assessed by performing successive line searches with teams of ten members, spaced at arm-length distance, once the plot-less searches or bomb exercises had finalized.

Under the experimental conditions, the plot (capture-recapture) methods resulted largely irrelevant due to the extremely high recovery rates obtained during the conventional line searches. Actually only one of the 4 searches of this type performed across exercises required more than two searches to recover all evidentiary items, showing recovery rates above 95% in all cases. The only exercise requiring more than two successive forensic line searches to recover all elements was the first search of *Exercise 1*. In this case 482 out of 500 elements

(96%) were recovered in the first search, seven in the second and four in the third, resulting in seven (1.4%) not located or recovered in two additional searches.

When the estimate approaches zero, or we do not find more items in a search, we can reasonably assume that the items remaining are virtually undetectable. As discussed above, this never required more than three searches, and in most cases the first two searches served to recover 100% of the evidentiary items.

The same strategy and calculation will be useful if lower recovery rates are observed. This is to say, if the second search still renders a high number of items, well above 5% of the initially recovered.

Item size, as expected, also played an important role. The average weight of the seven items missed in the search above was less than 0.4 g, with the largest item missing weighing just seven grams. As an example, human tissue samples around these sizes would be extremely difficult to spot and, even more importantly, would degrade very fast under natural conditions.

Chapter V

Conclusions

Discussion of Findings and Implications for Policy and Practice

Research Component 1

Equipment suggested for use in a mass fatality recovery effort is affordable, highly customizable, and has a high amortization. The protocols favor equipment that is already available to law enforcement for other duties over equipment that is specifically suited for mass fatality scenarios. The equipment detailed in each configuration has the ability for multiple uses for agencies both big and small. The configurations are expandable to customize a set-up for agencies of all sizes without losing functionality. All pieces of equipment in the configurations have steep learning curves, adding to their utility in the field and in every day operations for all types of agencies.

Research Component 1 demonstrated that recordation of all spatial data, including contextual information, can be collected in a timely manner without adding significantly to the overall recovery effort. This configuration allows for more efficient scene management, readily identifying searched and critical unsearched areas, and even the amount of evidence recovered or expected at the area. GPS units can also be used as a substitute for compasses during searches or initial scene inspections, allowing for much more precise initial scene sketching, and even direct real time transmission to the central computer in the command center.

Research Component 2

Separating personnel into individual teams allows for each team to work independently thereby increasing productivity. Because photography was recognized as the most time intensive aspect of the recovery effort, two Photography Teams were included in one unit. It was shown that the inclusion of two Photography Teams increased productivity and did not jeopardize the integrity of the barcoding system.

As discussed above, the learning curve for each piece of equipment is steep. Once the Provenience Team adjusted to the team dynamic, spatial points could be collected with the total station at an average of 30 seconds per point. Using the survey-grade GNSS, this rate was reduced to an average of 10 seconds per point. The expedited times did not effect recovery rates, which successfully identified and collected greater than 90% of material (as discussed in *Research Component 3*).

Research Component 3

Research Component 3 demonstrates the applicability of standard density estimation methods to assess the amount of evidence remaining at the scene at each moment, and its spatial distribution in real scenes and in real time. Distance sampling methods appear very promising as cost-effective, quick methods for scene assessment, requiring minimum personnel, and being very robust for inter-observer differences or anisotropic distributions.

Plotless methods can be utilized when the initial search is reasonably effective, and does not require excessive scene post-processing. The methods can be applied to the spatial data as they are recorded, during regular recovery, and thus will not add additional tasks to the protocols. Both density methods can be extremely useful for scene management, helping to decide which areas require further processing, or may be released with minimum risks. The estimates can even be readily extrapolated to unsearched areas, if they are contiguous with processed ones (Borchers *et al*. 2004, Buckland *et al.* 2001). It is also possible to estimate the number of searches necessary to attain a recovery rate under a certain value. Finally, and interestingly, the availability of count points (spatial data) and density estimates opens the possibility of modeling factors such as explosion dynamics, which could help to better establish search parameters, or of assessing patterns of spatial association of the remains, useful in victim identification.

Implications for Further Research

With the protocols established, along with data acquisition, management and storage, future research should focus on better inter-connectivity in the field for real-time updates and reports throughout the recovery efforts. There is also a need for better intra-connectivity between the field and the disaster morgue. This could be established with newer technologies and the utilization cloud computing.

Newer technologies could also be used in the field for better documentation and on-site analyses. In the event of a confined crash site, three-dimensional scanners can be used to scan the scene and estimate the volume of the debris field, which in turn, will help with personnel and needs cost assessments necessary for a particular site.

The plotless methods used in *Research Component 3* can also introduce and analyze other parameters. Cluster size can be examined to estimate the dispersion of remains from a single individual to possibly aid in identification. Also, the recognition of gradients from the crash site may help detect or predict where remains are likely to be found, as well as areas that do not require further processing.

Lastly, more protocols need to be developed for other potential scenarios. As shown in *Research Component 1*, different scenarios, like the condensed crash site of Clarence Center, NY, and dispersed crash sites, such as Flight 93, require slightly different recovery protocols. Scenarios such as a plane crash in an urban environment, or natural disasters such as tornadoes, remain to be investigated with specific protocols.

Chapter VII

Dissemination of Research Findings

Funding from the NIJ has afforded the investigators the opportunity to disseminate information on effective and efficient scene processing protocols for mass disaster incidents to a large number of law enforcement, forensic investigators, and coroner/medical examiner office personnel. Dissemination efforts throughout the project duration included yearly short courses, special workshops, training exercises, and lectures at regional and national meetings. These dissemination opportunities also provided the impetus for testing subsequent modifications to the *Weldon Spring Recovery Protocols*, which in turn, provided the foundation of the research described.

The most significant testing and dissemination efforts occurred during the post-bomb blast recovery exercises conducted both during a short course presented yearly at Mercyhurst College and the additional training and research exercises permitted by the grant. These training exercises permitted the effective dissemination of information to law enforcement (including FBI), federal agencies (including NTSB), and other state and local agencies participating in the exercises. A great deal of feedback was obtained from the exercises that helped in the production of the final scene processing protocols included in this report.

In addition, descriptions of the project, protocols and results have been presented at regional meetings including the annual Kentucky Coroner's Convention in Louisville, KY; the annual New York coroner's convention in Rochester, NY; the annual Michigan Medical Examiner's meeting in Mt. Pleasant, MI; Region V DMORT training in Kokomo, IN; the Medicolegal Death Investigation Course for new Pennsylvania coroners in Hershey, PA; the North East Forensic Anthropology Association (NEFAA), NIJ focus group in Alexandria, VA; Ontario Police College, Alymer, ON.

The research has been highlighted in presentations at the national level including the annual National Meeting of the National Association of Medical Examiners (NAME) in San Francisco, CA; the American Academy of Forensic Sciences (AAFS) in Chicago and Seattle; American Association of Physical Anthropologists (AAPA) in Minneapolis, MN; NIJ Conference in Arlington, VA; NIJ's Syracuse University Dialogues in Forensic Sciences, Syracuse, NY; and the Dungarvan Global Intelligence Forum, Dungarvan, Ireland.

Descriptions of the protocols have also been presented in a chapter on mass disaster (*Forensic Anthropology at the Mass Fatality Incident (Commercial Airliner) Crash Scene* by DC Dirkmaat) and in the soon to be published book *Companion to Forensic Anthropology* (DC Dirkmaat, editor).

CHAPTER I
INTRODUCTION

Statement of Problem

Significant lessons have been learned in the aftermath of the terrorist attacks on the US on September 11, 2001. Disaster management plans have been created for municipal, state and federal agencies and deal with issues as diverse as pre-incident planning for first responders, forensic identification of victims, and addressing the needs of the victims' families. However, one area that is incompletely addressed is how to properly "process" the mass fatality scene. A position paper by Homeland Security (*National Preparedness Guidelines*, September 2007) provides two important directives: 1) all of the human remains are to be recovered from the scene, and 2) "complete documentation and recovery of human remains and items of evidence" must be executed. Related to this idea is that "law enforcement agencies are given all information needed to investigate and prosecute the case successfully (*NPG* 2007, pg. 8)." These directives also stress that: 1) mass disaster scenes are to be considered crime scenes and customary rules of evidence and chain of custody apply, and 2) all human remains must be recovered.

When faced with the prospect of "processing" a large-scale incident, the sheer volume of material present at the scene often overwhelms investigators, who then tend to minimize the importance of proper and detailed documentation of the spatial distribution of the remains. It is assumed that the information to be gleaned by expending time and effort in the precise documentation of the location of items at the scene is negligible and cost-in-time for such effort is appreciable. Thus, the emphasis is on removing the evidence from the scene as quickly as possible with little or no provenience (precise spatial location) documentation in order to begin the process of identifying the victims, determining the cause of the crash and clearing the scene of all crash debris.

Contrary to the current belief, the provenience of this evidence is extremely important for a number of reasons: 1) it can be an important aid in victim identification, 2) it can provide evidence of the manner of crash, and (as noted above) 3) it constitutes physical evidence related to a potential crime scene, and therefore must be carefully documented *in situ,* in order to establish chain of custody and maintain prosecutorial significance.

Poor or incomplete recovery methods also affect decisions regarding whether the site is "clear" of evidence and debris, and can be released to the public. All forensically significant evidence must be documented and collected prior to releasing the scene. With high profile cases such as a plane crash, this consideration is further compounded by the fact that the scene and locality will attract a lot of attention from the curious public and souvenir hunters. Public detection of *any* human remains has significant negative implications for families and the media. In addition, the media and public perception of a too prolonged, inconsistent or inefficient recovery effort at a terrorism scene has enhanced negative consequences given the essentially propagandistic nature of terrorist strategies (Abrahms 2005 and 2006, Drake 1998, Wilkinson 1997 and 2000).

The field documentation and recovery of physical evidence associated with mass fatality scenes, such as airplane crashes or bomb incidents, is a tremendously complicated undertaking. This is due to three interrelated factors: 1) the sheer volume of fragmented human remains and other physical evidence, densely concentrated and anisotropically distributed at the scene, 2) the large size of the debris field created, and 3) the accordingly large number of personnel, equipment and other resources required to process the scene.

If the decision is made to conduct a comprehensive forensically-sound recovery of the scene while removing nearly all of the crash debris, a great deal of planning and logistic considerations are required in order for the process to be completed both *efficiently* and *effectively*. An efficient recovery is one in which human and equipment resources are well orchestrated, and the process is completed in a timely manner. An effective recovery is one in which data are collected in a manner that is useful for victim identification, association of personal effects, determination of cause and manner of crash, and has maximum prosecutorial value. Consequently, well-thought out and detailed guidelines and protocols relevant to the processing of mass fatality scenes should be available to all groups responding to the incident, particularly prior to the incident. However, detailed protocols for these purposes are currently unavailable to most first responders.

The scene recovery methodology itself, based on forensic archaeology principles, *does exist* and has been successfully applied in several mass disaster scenarios. Additionally, key technological components and enhancements to the recovery methods are readily available in most law enforcement and first responder agencies. Applied to a variety of outdoor crime scenes such as surface-scattered human remains, buried bodies, and fatal fire victims, forensic archaeological techniques have proven very successful in the recovery of spatial data from these scenes by the principal investigator for the past 20 years. Through its focus on detailed documentation of specific location at the crime scene and relative to surrounding contextual features, forensic archaeology provides a perfect way to establish forensic chain of custody.

The principal investigator has been instrumental in developing large-scale mass fatality scene recovery guidelines and protocols focused on the use of total stations to guide the recovery efforts that have been field-tested. These protocols have been embraced by the FBI and are routinely presented in training sessions, following the successful utilization of the sequentially arranged recovery steps at a small plane crash in Missouri. Still, additional testing and enhancement of the method, through the incorporation of new technologies, were urgently needed in order to allow for its utilization by other responders, and for interagency cooperation and data sharing. It is difficult to effectively emphasize the need and importance of incorporating technological enhancements into mass disaster protocols. As noted by Ritter (2007) for laboratory operations “advance planning for using information technology in sample tracking and management saves time, speeds identification, and improves testing reliability. Without sophisticated software, the nearly 1,600 identifications made and nearly 20,000 human remains profiled in the World Trade Center identification effort would not have been possible. A laboratory responding to a mass fatality event must be prepared to track the physical location of each sample and the data associated with it through the entire identification process.” The same principle is directly applicable to scene recovery.

Building on previous research and experience by the principal investigator, the primary purpose of the proposed project was to significantly improve the efficiency and effectiveness of forensic “processing” (location, documentation, and recovery) efforts at large-scale crime scenes, and specifically, large-scale mass fatality incidents. The improvements in scene processing were accomplished through the development and dissemination of enhanced, realistic, effective and affordable search and recovery protocols that maximized the detection, recovery and identification of human remains in mass fatality events. Important provenience data was acquired in a standardized manner which has benefits to real time recovery efforts as well as reconstructing past events related to manner of crash or bomb incident. The applicability of these enhanced protocols to a variety of other outdoor crime scenes was also addressed.

Review of Current Literature

Response efforts during the events of September 11, 2001 were more than reasonably effective (see Sledzik *et al.* 2009) given the relative lack of preparation for the nature of this type of threat. These events triggered a massive effort to improve disaster management planning at all governmental levels, resulting in a seemingly well-prepared government infrastructure and first response system, as evidenced by a review of some of the highest profile plans and widespread publications (e.g., Alexander 2002, ASIS International 2003, Butler *et al.* 2003, Department of Homeland Security 2007, NIJ 2005, Stallings 2002).

The development of the federal government's Disaster Mortuary Operational Response Team (DMORT) represents the most relevant development in the role of forensic anthropologists in mass disaster response. DMORT has developed and implemented highly efficient and effective victim identification protocols (London *et al.* 2002 and 2003, Saul and Saul 2002, Saul *et al.* 2000 and 2003). Efficient collection of antemortem data (by the Family Assistance Center Team, FACT) combined with effective forensic databases *(Victim Identification Program VIP, and WIN-ID),* have vastly improved antemortem and postmortem comparison of biological data for victim identification. The case of United Flight 93 provides a perfect example of these improvements (Dirkmaat and Miller 2003, London *et al.* 2003, Sledzik *et al.* 2003 and 2009).

Most of the anthropological and odontological literature on mass scenes has focused on identification issues and the commingling of human remains. Research on commingling issues has traditionally focused on typical or human right cases (for an excellent review of literature of commingling research see Adams and Byrd 2008, and references therein). Sledzik and Kontanis (2005) and Kontanis and Sledzik (2008), are probably the only two references specifically addressing the problem specific to mass disaster scenes.

Especially relevant for this project, Tuller *et al. (*2008) demonstrated the importance for victim identification of scene spatial data collection. Metric and non-metric anthropological methods alone tend to perform poorly in large-scale commingled victim scenes, often with successful identification rates below 50% (e.g., Ubelaker 2002). Conversely, the combination of biometric techniques with the analysis of the precisely noted spatial distribution of the remains has been reported to produce successful identification rates close to 100% (Tuller *et al.* 2008). It has also been shown that the spatial association assumption underlying these analyses (i.e., those potentially conjoining remains that are spatially closer to each other are more likely to belong to the same individual) still apply to scenarios with highly disturbed and fragmented human remains (Dirkmaat *et al*., 2005). Results of preliminary studies from car bombing exercises performed at Mercyhurst College (Erie, PA) from 2005 to 2008 strongly suggest that the same spatial association assumption can be extended to personal effects, which may provide important presumptive identification clues.

Victim identification is still the major goal of forensic anthropology efforts at these mass fatality incidents (Sledzik 1996 and 1998). However, after the 9/11 events, every mass fatality involving explosions or vehicle crashes has become a potential crime scene, requiring appropriate forensic processing methodologies. Still, unlike victim identification, scene recovery and processing, especially after release by Federal agencies, has received scarce attention. Even when Homeland Security directives request “complete documentation and recovery of human remains and items of evidence” (Department of Homeland Security 2007, pp. 8), no discernable guidelines or exact protocols are offered to accomplish this objective.

Probably the only comprehensive description of detailed mass scene forensic protocols, as applied by major law enforcement agencies, is found in Reinecke and Hochrein (2008). This reference describes the main guidelines and procedures currently followed by FBI ERT teams, accompanied by an excellent literature review. The basis of the mass scene recovery protocols described in that article were developed by the principal investigator (DCD) and FBI Special Agent Hochrein (Dirkmaat *et al*. 2001) and are based on forensic archaeological techniques (Dirkmaat 2001, Dirkmaat and Adovasio 1997, Hochrein 1997 and 2002, Morse *et al.* 1983, Skinner 1987, Sledzik *et al.* 2007). Forensic archaeology maximizes location and recordation of the exact position of physical evidence relative to other evidence and the contextual setting, often providing key information to reconstructing events surrounding death and victim emplacement at the scene (Dirkmaat and Adovasio 1997).

The protocols were initially formulated following the on-scene documentation of the physical evidence associated with the 1994 crash of USAir Flight 427 in Pittsburgh by members of Mercyhurst Archaeological Institute (MAI) (Dirkmaat and Quinn 1995). This project served to demonstrate that comprehensive and efficient spatial documentation of evidence is possible within a reasonable time span at these types of scenes, when a total station system is utilized. Nearly 10,000 crash remains were precisely plotted without a significant increase in processing time (MAI 1994). Total stations are now part of the standard equipment of most law enforcement agencies. However, this technology has not been routinely implemented on subsequent mass fatality incidents, likely due to lack of explicit guidelines on how to apply them to these scenes.

A second lesson gained from Flight 427 and a mock exercise in Columbus, OH (Dirkmaat and Quinn 1995), was the utility of an approach based on integrated, discrete, sequentially-arranged, running-concurrent steps, to be completed by trained teams of small numbers of individuals. This tactic drastically reduces processing time and on-site disturbance of evidence. This protocol was tested during a FBI training seminar in St. Louis, MO (Dirkmaat *et al*. 2001, Reinecke and Hochrein 2008) carried out in the small town of Weldon Spring, MO, and for simplicity we will refer to the resulting mass scene processing protocols as the *Weldon Spring Protocols*.

This exercise served to illustrate the effectiveness (i.e., how much of the physical evidence was located) and the efficiency (i.e., speed and accuracy of the documentation process) of the new processing methodologies relative to standard recovery methods not involving the recordation of exact spatial coordinates of the remains. Four sequential though concurrent steps are involved: 1) intensive and thorough search for and location of physical evidence, 2) total station data collection of three- dimensional spatial data and assignment of field specimen numbers, 3) photographic documentation, and 4) physical evidence collection and preservation and removal from scene. The *Weldon Spring Protocols*, far from resulting in increased recovery times, actually reduced processing time significantly, while increasing detection and recovery rates (Dirkmaat *et al.* 2001, Reinecke and Hochrein 2008).

The efficacy of the *Weldon Spring Protocols* was tested almost immediately in a real situation, involving the tragic crash of the small aircraft carrying Missouri governor Melvin P. Carnahan and three other individuals (Reinecke and Hochrein 2008, National Transportation Safety Board 2002). The recovery was completed within five days, and representatives of all the involved state and federal agencies agreed that the new protocols were invaluable in collecting all important evidence and human remains, even given the adverse conditions.

Rationale for Research

The primary goal of the project was to *significantly improve the efficiency and effectiveness of forensic "processing" efforts at large-scale mass fatality scenes*. This goal was accomplished by conducting research relevant to: 1) enhancing and testing newly-configured documentation and recovery protocols to optimize the detection and recovery rates of physical evidence, while minimizing time, equipment and personnel costs, 2) producing user friendly and meaningful information technology protocols and tools to enhance data collection, sharing, integrity, and security at these scenes through the integration and testing of state-of-the-art (though, common) technologies, which will dramatically reduce recording time, errors and duplication, and 3) scientifically testing the efficiency and effectiveness of the newly developed technology configurations.

The research contains the following objectives, integrated into three research components. The first required the development and validation (field testing) of two different technological configurations for the implementation of the *Weldon Spring Protocols*, as well as the accompanying training and information materials and tools. Each of these configurations represents the low- and high-end alternatives, in terms of costs and resources, allowing for complete, efficient and effective implementation of the *Weldon Spring Protocols*. These alternative configurations permit each agency to configure their own system, likely as an intermediate solution between both alternatives, based on their needs, resources and capabilities.

The second research objective was to test the *efficiency* of the new technological configurations in terms of time and personnel required for their successful implementation. The third objective was further testing the technological configurations and resulting protocols in terms of *effectiveness*, measured relative to recovery rates. As a secondary output of the third objective, field and statistical methods for the reliable assessment of the amount of evidence present at a given time at a particular scene area were produced.

Introduction to Research Components

Technological protocol configuration, validation and budgetary cost assessment constitute the basis of the first component of the research project (*Research Component 1*). We employ the term *validation* to distinguish practical protocol testing in terms of its functionality (e.g., software and hardware compatibilities, system stability, user-friendliness, etc) from the statistical hypothesis testing of protocol outcomes. Statistical protocol testing was divided into two research components, aimed at testing the efficiency of the new technological configurations of the *Weldon Spring Protocols* in terms of time and personnel costs (*Research Component 2*), and their efficacy in terms of recovery rates (*Research Component 3*).

Each of the three research components impact to varying degrees all of the other research components, since they were configured to be tightly interrelated. *Research Component 1* targeted primarily the *Weldon Spring Protocols Steps* 2 through 4 (data and evidence collection and sharing). *Research Component 2* examined the duration and efficiency of the protocols as a whole. Finally, *Research Component 3* primarily targeted *Weldon Spring Protocols* Step 1 (evidence search and location). The research components were developed concurrently, and during the same exercises, in a battery of tests progressing from simpler, more controlled scenarios, to more complex, realistic ones.

CHAPTER II

RESEARCH COMPONENT 1: PROTOCOL CONFIGURATION AND VALIDATION

Materials and Methods

Introduction

The primary goals of *Research Component 1* were: 1) incorporating, configuring and validating recent technological advances for data collection (especially spatial data), enhancing detail and speeding up scene documentation while reducing human-induced errors in data collection and management, 2) expediting on-site data transmission and integration, which will result in new and enhanced abilities to conduct on-site data analysis and offsite data sharing, 3) producing simple and meaningful guidelines and check lists for needs assessment and step-by-step technology configuration, aimed at law enforcement and first responders, and stressing the use of already available equipment, and 4) creating comprehensive but straightforward descriptions and training educational materials detailing each step of the recovery protocols, as well as their primary goals and objectives.

As explained above, this component does not include direct statistical testing, although the resulting protocols and alternative technological configurations were refined and tested for efficiency and effectiveness in *Research Components 2* and *3*. Thus, no quantitative data were treated in this component.

Research Design

The proposed technological configurations were based on protocols routinely employed by AFS Mercyhurst College during all forensic recoveries of small-scale outdoor crime scenes. Modifications to the basic recovery methodology, applicable to large-scale mass fatality scenes, were developed by the principal investigator on the basis of his experiences at a variety of mass disaster scenes, including the crash of United Flight 93 in Somerset, PA (see *Statement of Problem* and *Review of Current Literature* in the Introduction section of this report).

As the needs and resources of each agency employing the recovery protocols will vary, two different technological configurations were developed and validated, representing the low- and high-ends of the fully operational options. The main differences between the two configurations are based on data transmission protocols. These two configurations are discussed in more detail below.

Data recording devices included total stations, GPS units, digital photographic and video recording equipment, bar-coding equipment, and hand-held PDAs. A central computer performed data integration and analysis at the mobile command center. The key technological element of the *Weldon Spring Protocols* is the total station, not only as a recorder of precise and accurate three-dimensional location of individual items of evidence, but also as the element assigning a unique field specimen number. The function of creating unique identifier numbers for individual pieces of physical evidence serves to eliminate duplication of evidence numbers (a problem that has plagued previous systems in which humans provided the numbers). Also to consider, when processing large scenes, more than one total station is typically required and employed. There are risks, primarily for data integration, associated with the simultaneous and alternative use of multiple total stations. Though, there is a simple solution by assigning a unique data prefix to each total station, and cross-referencing their locations in the field, but the task is much easier if clear and straightforward standard guidelines on how to incorporate multiple instruments are provided and followed by all responders (see *Results* section below).

Personal digital assistant (PDA) computers were used to collect contextual data in the field. The corresponding databases were based on the ones previously developed for small-scale scene recoveries by AFS Mercyhurst, requiring minimum typing. A variety of software platforms and PDA models were evaluated, all with Bluetooth capability. These affordable devices are included in both low end and high-end configurations. The data recording databases, containing reference number, spatial coordinates, and media files related to field documentation, were designed to maximize their compatibility with current morgue operation databases. In this way, forensic anthropologists, forensic odontologists, and forensic pathologists will be able to look for potential biological specimen matches, or to search for identifying personal items, on the basis of proximity of fragmented remains to each other at the scene.

A bar coding system was used in the high-end configuration to label flags and recovery bags, reducing reference search and notation for the photography, recovery and morgue teams. Searches and the subsequent location of evidence were also enhanced, as was general onsite management, through the use of GPS data. If appropriately used, GPS units serve to geo-reference the scene with great accuracy. That is to say, to assign an absolute location to each item in a geographic coordinate system such as latitude/longitude or the Universal Transverse Mercator (UTM). In the protocol (currently in use by AFS Mercyhurst), the location of each total station and four accompanying total station points will be recorded with a Trimble Geo XH GPS. Whenever possible, the four points must approximately form a square, with sides no shorter than 35 feet (around 10 m). These points will serve to superimpose and orient the total station map, geo-referencing it with sub-foot accuracy. The distances between points obtained from the total station and the GPS measurements will also serve to estimate the GPS error. The four-point system allows for easy, superimposition of the total station and the GPS references in ArcGIS and other common mapping programs, with sub-feet error. Alternatively, the Trimble R8 can be used to record the precise geographic location (often sub-centimeter accuracy) of the datum upon which the total station will be placed. This way, the precise coordinates can be entered into the total station to negate the need for geo-referencing after the fact.

Through these configurations, the total station coordinates can be immediately plotted and referenced on an existing map, satellite or aerial photographs, which can be uploaded into the central computer, or even directly into the total station data recorder. Online protocols and geographic resources are readily available for the law enforcement community (see NIJ *Mapping and Analysis for Public Safety* program, http://www.ojp.usdoj.gov/nij/maps/).

The central computer configuration included a ruggedized laptop with wireless Internet connection, Bluetooth and or WiFi (IEEE 802.11 a/g protocols) capabilities, and GIS software. A printer and plotter were available on site in the high-end configuration. This computer contains all software to collect and integrate all data from secondary on-scene data recorders.

In the low-end mass fatality scene data recovery configuration, peripheral components were not wirelessly interconnected, and data was uploaded manually to the central computer after a data collection session was completed (known as batch storage). This is a simple alternative, readily accessible to most law enforcement agencies, even at the local level. However, given that data assessment and analysis will typically only be possible after evidence removal, this configuration does not allow for on-site correction of potential errors, presenting some data integrity risks, such as a software or hardware failure in a hand held PDA, erasing all data collected before an opportunity to batch store on the central computer.

The high-end configuration was characterized by enabled wireless data sharing and transmission between peripheral components. This allowed for more secure onsite data evaluation and backup. In particular, the unique numeric reference assigned by the total station was remotely entered into a bar-coding database.

An adhesive bar-code label replaced writing the field specimen number on the flag. In turn, this barcode was automatically read and entered into the portable (PDA) database forms of the documentation and recovery teams, virtually eliminating writing notation errors and delays.

Following needs and resource assessment, each agency will be able to define its most feasible configuration, in most cases an intermediate solution between the proposed high and low end alternatives. The resulting technological protocols were tested and refined through the exercises in *Research Components 2* and *3*, including the participation of law enforcement officials and first responders.

Research Component 1 initially provided the successive protocols to be tested in *Research Components 2* and *3*. The technological configurations and related guidelines were gradually refined, modified or, when appropriate, abandoned, as new information was gained from the practical exercises. Ultimately, this process concluded with the production of the definitive protocol guidelines and configurations. The deliverables produced by this component include: 1) detailed recovery protocol descriptions for dissemination, formatted as straightforward, meaningful education and training tools, 2) comprehensive and straightforward guidelines for needs assessment and protocol implementation, including alternative solutions and configurations, and covering aspects such as approximate costs or software configuration and problems, and 3) a user-friendly, free relational database for data collection and integration, in different formats for PC and PDAs. Open software and the most extended databases were favored, maximizing compatibility with other related solutions, such as crime mapping software or Victim Identification Program (VIP) developed by Don Bloom, and the dental identification program WINID, developed by James McGivney.

Results

Technology Configurations

Handheld Computers/Barcode Scanners

There are a variety of handheld computers currently on the market. Examination and testing focused mainly on handhelds with barcoding capabilities, as these are considered key for eliminating data ambiguities, reference duplications and recording errors. In addition, through the assignment of a unique bar code to each item, which can then be read by all the independent recovery teams (namely the *Photography* and the *Collection Teams*), recording times can be reduced.

A number of different models of handheld computers have been examined based on their functionality, range of application (related to their amortization), and pricing. The price/utility value of each piece of equipment can be properly evaluated when comparing inexpensive and more expensive alternatives.

Low-end handhelds with bar-coding capabilities are available at prices not far from regular PDAs (in the range of $500-800). Among these, the *Motorola Symbol* series appears to be one of the best options, with a wide variety of affordable scanners (see http://www.barcodediscount.com/catalog/symbol/mc17a.htm). They utilize WiFi to constantly connect to a server, thus they can also be used in higher end configurations. The major drawback found in these machines is that their operating system (OS) is very limited, requiring specific customization for its application to mass disaster response. They also exhibit low flexibility and limited application outside of the connection to a server. Therefore, it appears unlikely that the equipment would be of much use to the purchasing agency outside of emergency management.

As a result of these considerations, several configurations, ranging from low-end converted PDAs to high-end all-in-one ruggedized scanners, were tested. The *Trimble Nomad* represents a high-end alternative, with a price around $3,500, but contains a much larger amortization potential because it can be used in many other applications beyond emergency management (Figure II-1). One of its main advantages is that it runs *Windows Mobile 6*, resulting in a machine with very high versatility and compatibility with most laptop and desktop equipment. It is equipped with a 1d laser scanner, which is sufficient for the bar coding needs of the protocols (it performed extremely well in the field exercises described in the Methods section, carried out under very intense daylight). It has the ability to read several barcode types, but most importantly CODE 128. As a result of this software configuration, this handheld can run the *TracerPlus Standard* database for Windows Mobile/CE, compatible with most standard desktop databases (see *Barcode Databases* below), and is extremely easy to configure for almost any other application, including regular evidence or equipment asset tracking and storage. Additionally, The *Trimble Nomad* is equipped with a GPS receiver, a two-megapixel camera (which can be used for back up information), WiFi (802.11g connection) and Bluetooth capabilities to streamline information sharing processes. Importantly, it is a suitable "rugged" handheld that is made to withstand marginal environments and heavy use in many other law enforcement applications, likely extending its life. However, these additions consume more battery life. A full charge will last approximately five hours with minimum to moderate use (using just barcode scanning/databasing).

The *Nomad's* largest drawback is its size. While it is ruggedized to withstand harsh environments and a heavy workload, it is not especially ergonomic, particularly to left handed users. The large body is also fairly heavy for a full day of work in the field. It cannot be easily affixed to a belt or stored in a pocket when idle.

Figure II-1. The Trimble Nomad handheld barcode scanner. The posterior view shows the storage of the stylus and hand band.

The *Huskey FexScan ($2,449.00)*, on the other hand, represents a mid-range alternative in terms of both flexibility and portability (Figure II-2). It uses an older version of Windows Mobile CE, which considerably lowers both its versatility and ease of use. The larger size of this device reduces its portability, although in exchange provides the advantage of a full QWERTY keyboard. It lacks a USB hub and links through either a serial adapter or SD flash cards. Importantly, it contains a pocket version of *Microsoft Access* for easy database creation. This handheld would be included in a mid to lower end configuration. Although its utility/price is somehow intermediate among the alternatives described above, its compatibility with desktop databases, availability of options such as waterproof sealing, and larger size still makes it a useful tool, especially as an alternative to more expensive ruggedized laptops. It also has the added advantage of barcode capabilities. Therefore, it has a higher amortization potential than more basic handhelds. It performed very well in the field exercises described below as a barcode station for the reception and sorting of the items recovered by the Collection Team, and could be a good alternative for linking the Scene Recovery and Morgue Reception Teams at a mass fatality incident.

Figures II-2. The Huskey FexScan handheld barcode scanner with a full QWERTY keyboard.

Lastly, *HP iPaq (100 and 200 series)* PDAs are considered at the low-end range (Figures II-3 and II-4). These PDAs were fitted with external barcode attachments. The *HP iPaq 211* ($375) was fitted with a *Socket Type II CF Scan Card* ($350; Figure II-5 below) and the *HP iPaq 111* ($300) was fitted with an *SDIO Scan Card 3P Class 2 Laser* ($300). Both machines ran on *Windows Mobile 6* like the *Trimble Nomad* and also utilized the *TracerPlus Standard* asset tracking and databasing software. These handhelds both worked as well as the *Trimble Nomad*, but had a much shorter battery life. Each machine had about a four hour working window. These combinations are also not ruggedized and should not be handled as such in the field. Their smaller size, however, did allow for belt attachment, as well as pocket storage during idle time. Both *iPaq* models are only capable of a “soft” shut down between usage (similar to a computer sleeping or hibernating). This can be sometimes cumbersome when dealing with long-term storage of the device.

Figures II-3 and II-4. The HP iPaq 100 and 200 series PDAs, respectively.

Figure II-5 .The Socket Type II CF Scan Card, which was fitted into the PDAs.

Barcodes

Several different code systems were researched and examined. CODE 128 is clearly the optimal alternative for the protocols, particularly as it utilizes the full 128 ASCII character set. The alphanumeric set permits codes to contain both numbers and letters. It also displays text below the barcode for easy identification without a scanner. CODE 128 is also a self-checking code and includes a checksum, which is an algorithm aimed at ensuring that the code says what it is intended to say. These can be customized on a case-by-case basis in order to maintain data organization and integrity. Other codes examined, such as ISBN, various EANs and UPC, do not offer nearly as much information, flexibility and reliability.

Barcode Generating Programs

Both *BarcodeGenerator* ($45) and *WaspLabeler* ($95) programs are viable options among the software programs specifically examined for this grant. They are extremely user friendly, and each will easily code the entire spectrum of barcodes simply by direct user entry of the information intended to be contained in the barcode. Each program also has the option of adding personalized graphics to the barcode label. This could be an identity tag for the organization, etc.

BarcodeGenerator has a user-friendly interface and is capable of creating single codes simply by typing in the information you want on the barcode. This is useful when only a couple of barcodes are necessary. *BarcodeGenerator* cannot create "batch" codes. It does, however, have the ability to create codes in PDF417 and Datamatrix. This might be preferred depending on the amount of information needed within a code.

WaspLabeler has the advantage of generating a preset number of serialized barcodes with a unique identifier. This allows the instant creation of a site specific, serialized barcode. The learning curve for this software, however, is quite steep.

Printers and Labels

The authors have found that barcodes need to be of a certain size and resolution to be effectively read in the field during recoveries. Therefore, printers must support certain sized labels, and importantly, print labels at a high enough resolution (greater than 200 dpi) that do not bleed ink or produce blurred barcode images. Laser printers are preferred, but inkjet printers can work as long as the size is large enough. In terms of the labels themselves, Avery 1" x 2-5/8" labels (Avery Product # 8160) are recommended for inkjet printers. The same label size can be used for laser printers as well (Avery product # 5160), but since laser printers offer finer details, smaller labels can be easily scanned, such as 1/2" x 1-3/4" labels (Avery # 5267 labels). On the other hand, the advantage exhibited by the larger labels in the exercises was that observers more easily read the larger text. Therefore, barcode label sizes will be critically evaluated in terms of field equipment and ease of use. Larger labels will be chosen over smaller ones when some of the teams (*Photography*, *Collection* or *Reception*) are not equipped with scanners, necessitating manual entry of the written information on the label. On the other hand, smaller labels will be more effective in high-end configurations when all key teams are equipped with field barcode readers.

Among the alternatives researched, *Zebra* seems to offer the widest array of portable printers capable of producing labels quickly, and are recommended by many hardware manufacturers. The resolution of these printers does not exceed 200 dpi, though readable barcodes are still produced. However, these small printers are relatively expensive, with prices in the $1000 range. Therefore, whenever it is possible to have a central computer, it is recommended that a standard laser printer be used.

Additionally, the labels can be printed in advance so that the unique numerical references for each evidentiary item are read in the field from the barcode and then entered into the databases containing the spatial coordinates and item description, rather than the opposite. This configuration, involving a regular printer in a rugged, foam padded case, represents a much more cost-effective strategy, as compared to buying an expensive portable printer, or a ruggedized military-grade printer which offers few applications beyond those within mass fatality protocols. A printer with characteristics similar to the HP LaserJet 2420d may be a good alternative. An HP Laserjet P1006 printer was used in the field exercises with optimal results, but even a standard printer could print reliable labels cheaper and faster than the portable printers researched, especially when the right label size is selected and quality handheld scanners are employed (Figure II-6). Therefore, during needs assessment, budget allocation should favor better barcode scanners over more expensive printers if a budgetary decision between them is necessary.

Figure II-6. The HP Laserjet P1006 printer used in the field exercises.

Field Computers

After contacting manufacturers of the proposed equipment and examining the technical specifications of available models, most high end, ruggedized tablet PCs (such as MobileDemand XTablets of the T8700 and T8600 series) have been discharged from consideration in the final configurations (Figures II-7 and II-8). Even though many of these computers exhibited promising technical specifications, such as integrated bar-code readers and software, they are deemed to be cost ineffective when compared with more conventional alternatives, such as the much cheaper Panasonic Toughbook series. A key characteristic of the Toughbook that makes it a better alternative is that most other high end, ruggedized tablet PCs seem to rely on small solid-state hard drives. These hard drives offer higher stability and durability, as they lack mobile parts, but generally at the cost of disk capacity, offering storage capacities of around 8 to 16GB, insufficient to host conventional operating systems (e.g. Microsoft Vista) or mapping programs (from the ArcGIS family).

Figures II-7 and II-8. The Panasonic Toughbook field computer.

Given this storage capability issue, and the need to rely on lighter portable computers, as opposed to conventional desktop/laptop solutions, ruggedized handhelds, such as the Rugged Notebook Nomad series, offer a much better alternative for data collection during the initial phases of the recovery protocols, at a cost of barely 30% of that of the high end TabletPCs.

The Trimble CU and TC Controller series have also been identified as optimal, cost effective alternatives for the initial collection, storage, and field transmission of total station and GPS data (Trimble R8), as they can connect directly to each of these instruments, and can even control both devices remotely in a very user-friendly fashion, which saves configuration time and complexity. These devices are Microsoft Windows based (running on the Windows® CE.Net operating system), making them easily connectable to regular PC computers, at a competitive price.

Alternative field networking systems have also been examined, with a special focus on security issues. As explained in the original project, a mass disaster scene, such as an airplane accident, is always a high profile scene, and data confidentiality is always a major concern. Encryption and data protection protocols have been examined relative to three main alternatives: Bluetooth, 802.11 wireless or WiFi protocols, and Novatel MiFi Personal Hotspot. While most of the equipment to be considered in this project (including total stations, GPS units, and even some photo cameras) include Bluetooth capability in their standard configurations, it has been observed that 802.11 WiFi network configurations offer a much larger transmission range and, especially important, better encryption protocols, thus offering much superior security standards. Additionally, WiFi routers (such as the Linksys Wireless G) can be purchased for under $100, and it is possible to add a series of signal amplifiers to ensure network coverage in a range wide enough to encompass the entirety of a large scale mass disaster site. However, Bluetooth connection/communication between equipment has also been tested. Bluetooth proved to work well communicating between devices, but the range of the signal is around 30 feet thus diminishing its utility in a mass disaster scenario. Lastly, the Novatel MiFi connects to a cellular network and broadcasts a WiFi compatible signal that can connect up to five devices (Figure II-9). This connectivity offers the mobility of Bluetooth with the security of WiFi. The devices connected to the MiFi must be within 10 yards of the MiFi to receive adequate signal strength.

Central Command Computer and Barcode Database

PTS Tracer Plus Wireless Server was installed on a standard Dell Desktop computer. The software could also be installed on a traditional server if so desired. The PTS Tracer on the handheld computers/scanners links up via WiFi to the server to deposit information in real time. If WiFi is unavailable, the database is also capable of batch processing and storage. Queries can be made within the server to track and link locations, and also to export it to other ODBC compliant databases such as Microsoft Access for incorporation of information from other sources, as well as long time curation of the information. For this type of server to work, the computer that is housing it must always be on and connected to the internet.

Figure II-9. The Novatel MiFi Personal Hotpot.

Survey-Grade GNSS

The Trimble R8 is a survey-grade GNSS (global navigation satellite system) that combines total station accuracy with high-resolution GPS accuracy (Figures II-10 and II-11). The R8 connects to an RTK (real time kinematics) network of established GPS points (base stations) to constantly update corrections for more accurate estimations of the R8's location. So long as there are at least four satellites and a connection to the RTK network, the R8 is capable of georeferencing, or assigning precise coordinate points on the earth's surface, at subcentimeter accuracy. This effectively eliminates the need for a traditional GPS and total station.

The R8 has the ability to work in denser canopies more accurately than traditional GPS units, however it cannot work indoors or in extremely dense canopied areas or near large standing objects such as large buildings, due to multi-path signal errors. The R8 also requires a connection to the RTK network either through a tethered cell phone or internet connection.

Figures II-10 and II-11. The Trimble R8 survey-grade GNSS (above) and Trimble TC2 handheld, ruggedized computer (right).

Coordinate Data Acquisition Software

A total of three softwares were tested for coordinate data acquisition; Evidence Recorder 5 was tested with the total station and TerraSync and Survey Controller were tested with the R8. All of the softwares have the ability to record points, lines and polygons within the program.

Evidence Recorder 5 is considered the "industry standard" in law enforcement. It is made to be linked directly with the CAD-based MapScenes. The interface is extremely user friendly, giving the ability to look at a real-time map as it is being made. Evidence Recorder 5 also keeps a time-stamped log of all of the proceedings (whenever a point is added, deleted, or edited) to enhance the chain of custody.

TerraSync is the user-friendlier of the GPS software applications. Once the program is setup for collection, the only information needed for input is a "comment", in this case the barcode number. TerraSync also allows the user to view the map in real-time. The most desirable aspect of TerraSync is the ability to export projects as shape files for use in a GIS program. This effectively removes a step from post-processing the coordinate data. TerraSync will not give the operator much flexibility in network and connection settings aside from setting a PDOP (position dilution of precision) threshold. TerraSync will also stop working in times of poor satellite geometry or too few satellites available for tracking.

Trimble Survey Controller has a higher learning curve than TerraSync, but offers finer control over network and connection settings, collection information, and satellite communication settings. Survey Controller allows for more detailed information collection, including an editable library for “class” or “type” of point (for this project: human tissue, vehicle part, etc.) along with the filename or “comment” (barcode number). Survey Controller also has the ability to do both simple and complex surveying math, such as calculating area of a polygon and distances between points. Survey Controller also has the ability to continue to work in circumstances of low PDOP. In these instances “float solutions”, or accurate point estimations based on prior points, are recorded. These are not the same precision as fixed points, but can be used for non-significant features where precise spatial context is not necessary, such as topographic points or other land features.

Section 1 Pre-incident Planning

Principle. Prior to the occurrence of an aircraft crash, a working, detailed plan for the recovery of human remains must be constructed and disseminated. The plan should discuss general recovery protocols for all evidence encountered (human remains, aircraft parts, personal effects, etc.), agencies involved, fiscal and material requirements, sequence of activities, and specific evidentiary items to recover (e.g., certain electrical and mechanical components from the aircraft). This plan will help to streamline the process by establishing a chain of command, outlining specific roles and duties for each agency involved, and helping mediate potential interagency conflicts. This plan should be imbedded in the overall mass fatality incident (MFI) plan.

Personnel. Representatives of the following agencies and disciplines: Coroner/Medical Examiner's Office (C/ME), NTSB, FBI, forensic anthropology, law enforcement, contracted personal effects agency.

Procedure. It is necessary to have a plan prepared for the sequence of activities and responders involved in a mass fatality incident after thescene is stabilized/secured and living persons are rescued. For a reference, consult the FEMORS Plan (http://www.femors.org/docs/FEMORS_FOG_3rd_Edition_Final_010507.pdf).

Topics to consider and to be discussed:

A. *Necessary agencies and when they are to be called***.** A list of each fire, police, utility companies agency's names, specific persons in each agency to contact, their contact information, and the information as to when these agencies should be contacted in case of a mass fatality incident should be created and available.

B. *Construct General Incident Command structure*, Identify potential locations of the Disaster Victim Identification (DVI) morgue. Four or five potential sites within a county should be identified in case of a mass fatality incident. Information such as accessibility and available space, electricity, running water, etc., should be taken into consideration when locating potential morgue locations.

C. *Identify Local Resources:* Equipment and personnel for both disaster morgue and disaster scene processing, including (but not limited to) the following:

1. *Assemble Morgue Supplies following DMORT Standards* (http://www.dmort8.org/DMORT%20NTSB%20SOP%20Nov%202006.pdf) including tables-specialized equipment / x-ray machines.
2. *Contact regional DMORT team for availability, requirements and resources.*
3. *Forensic Pathologists*.
4. *Forensic Anthropologists* (Forensic Anthropologists who are trained in archaeological recovery methods as well as human osteological analysis).
5. *Forensic Odontologists.*
6. *DNA Laboratory (AFDIL, or private companies)*.
7. *Forensic Photography.* This role can be filled by experienced local/state police personnel.
8. *FBI (local and regional offices).*
9. *Fingerprint Specialists*. *This role can be filled by FBI, or local/state police personnel*.
10. *Radiographic Machines and Operators. Contact local hospitals or private companies*.
11. *Local Red Cross*.
12. *Regional DMAT Team.*
13. *Refrigerated Storage. Contact companies that can provide some form of refrigerated storage, such as refrigerator trucks.*
14. *Lodging for personnel. Construct a list of hotels in the area, number or rooms, contact information.*
15. *Heavy Equipment and Operators.*
16. *Dumpsters.*
17. *Communication Experts.*
18. *Mapping Professionals. Check with local utility companies for GIS experts.*
19. *Portable Restroom facilities.*

D. *What to expect during the incident.* Discuss a variety of scenarios and bring in experts to assess options.

E. *Construct Preliminary Incident Command Structure (ICS).*

F. *Fiscal budget and resources.*

G. *Consider Training.*

Section 2: Procedure Immediately After the Incident

After fires are extinguished and survivors removed from scene, it is the responsibility of the relevant agencies (e.g. NTSD, FBI, Coroner/Medical Examiner) to meet and discuss roles and responsibilities. The NTSB will be in charge of the investigation if it is deemed an accident. FBI will be in charge of the investigation if it is deemed a criminal act. The C/ME is in charge of human remains. Other agencies and individuals will be brought in to assist in the recovery (Appendix 1 and 2 for Teams/Personnel and required equipment).

Part 1. *Initial Site Visit: Fact finding.* Representatives of the relevant agencies should make an initial joint inspection of the scene, in order to gather intelligence. Their quick, general evaluation of the scene should take into consideration the condition of the site as well as other pertinent details (Appendix 1: Figures 1 and 2).

Personnel. Representatives of each relevant agency including: Coroner/Medical Examiner, NTSB, Local Law enforcement, FBI Law Enforcement, Local Fire Department, Forensic anthropologist/archaeologist, Photographer, Videographer.

Procedure. Conduct an initial evaluation of the scene in preparation for final scene processing planning. Procedures and tasks to be completed during this site visit include, but not restricted to:

A. Determine extent of debris field, condition of the crashed vehicle, and completeness or fragmentation of human remains. Conduct visual inspection of the scene, take initial photographs, videotape the scene, take notes.

B. Assess the approximate number of dead, condition and the location of the biological remains.

C. Consider general working conditions at the site. What are the expected weather conditions over next one to two weeks; what are the external hazards (e.g., underground pipelines and electrical components) to consider?

D. Consider where to put security entrance/exit locations (Appendix 1: Figure 3), supplies, food, rest facilities, etc.

E. Develop a general recovery plan: how to approach the scene, who will be on-site and in what capacity.

Part 2. Detailed Planning Meeting.

Recovery organizers should convene a meeting to present information collected during the site assessment visit, discuss interagency communication, and finalize the details of the overall recovery plan (Appendix 1: Figures 4, 5 and 6).

Personnel. Representatives of each relevant agency including: Coroner/Medical Examiner, NTSB, Local Law enforcement, FBI and local Law Enforcement, Local Fire Department, Forensic anthropologist/archaeologist, Utility company representatives.

Procedure. Construct working scene processing plan that includes all agencies involved, establish ICS, determine locations for facilities (including Disaster morgue, Family Assistant Center), and construct scene recovery protocols. Procedures and tasks to be completed during this site visit include, but not restricted to:

A. Construct detailed ICS in order to establish interagency communication. Identify two individual representatives from each particular agency or service who will coordinate communication between the C/ME office, the agency or service, and the site. Establish a firm chain of command and communication to ensure proper command flow and to avoid disputes and discrepancies (Appendix 1: Figures 7 and 8).

B. Make final determination of sites for the incident morgue, the Family Assistance Center, and a Command center where agency/service representatives can report their progress and discuss changes or additions to the protocol or plan (Appendix 1: Figures 9 and 10).

C. Finalize Disaster Morgue location

D. Finalize Family Assistance Center location

E. Finalize Command Center location

F. Discuss roles and duties of all primary entities involved:

1. *C/ME*: Oversee scene management and coordinate recovery of human remains. Determine transportation and post-mortem examination (victim identification) procedures. Decide whether it will be necessary to call for assistance (e.g., DMORT).
2. *NTSB:* Oversee recovery of essential plane electrical and mechanical components to aid reconstruction of crash.
3. *FBI*. Provide extensive support capabilities
4. *Fire Department*: Monitor safety issues at the scene. Assist in recovery of non-biological evidence and as members of the Debris Removal Team.
5. *Law enforcement*: Maintain scene security and integrity. Provide assistance on the handling of non-biological evidence and general on-site recovery assistance. *Forensic Anthropologist*: Oversee crash site recovery of human remains using archaeological methods and evaluating forensic significance of biological tissue (bone vs. non-bone, human vs. non-human, and assessment of heat-altered bone and tissues).

6. Contracted personal effects agency: After excavation, collect, clean, identify, and store all personal effects before returning them to families.

G. *Finalize general recovery plan*. How to approach the scene, who will be on-site, and in what capacity) with Consider sequence of activities before, during, and after scene recovery.

H. *Determine what constitutes 'Significant Evidence,'* i.e., scene material that should be carefully noted (photographed and provenienced). Involves decisions on size and condition human tissue deemed 'significant', as well as personnel effects and vehicle parts (deemed significant by NTSB agents).

I. Discuss systems for site security and credentialing, site communications and data management, site safety and decontamination, and transportation of remains from the site to the morgue.

J. What is the accessibility of the incident site/ type of terrain: *What types of recovery vehicles will be needed? Are there lots of trees or buildings that might hamper GPS equipment? Any difficulties or effects caused by the landscape must be considered.*

K. Review aerial photographs of the crash site and debris field (Appendix 1: Figure 11).

L. Locations of atypical cases/remains*: It's important to note the locations and body positions of atypical cases in order to maximize evidence recovery. If one set of remains is in a much different position or circumstance than all the others, the area in question should be scrutinized for additional evidence.*

M. Potential number of remains for autopsy: *The morgue needs to be prepared for how much material will be incoming. It's also ideal to have an idea of how many people were in the vehicle or area involved in the disaster, if possible.*

N. Complicating factors, or level of difficulty in recovery: *Recovery personnel need to be briefed prior to entering the scene regarding what situations they will be encountering and if there are any sensitive circumstances surrounding site processing.*

O. Establish a Human Remains Tracking System: *Evidence security as well as general organization requires a remains tracking system. In addition to securing evidence and ensuring associated proveniences stay with the correct remains, there needs to be a consistent procedure for recording different sizes and types of human remains.*

1. Determine how the human remains will be numbered in the field, which biological remains (e.g., limbs, large pieces of human tissue, > 50% of a person) will be numbered. (See Appendix 3 for example protocols). Barcoded asset tracking technologies can be used to track fragmented portions of remains. Also creates chain of custody and a legally valid log of the history of that movement.

2. Determine how the numbers will be linked and easily cross-referenced with antemortem data such as VIP.

P. Establish an organization system for sorting the excavated debris: Separate locations and perhaps protocols need to be established for the different types of evidence such as vehicle debris, house debris.

Q. Determine types and numbers of personnel and equipment needed (Appendices 2 and 3).

1. Select an individual to oversee adequate restocking and distribution of supplies.

R. Discuss possible biological, chemical, physical or radiological hazards: Specific protective gear may need to be procured, and personnel may need to sign specific releases, or not be allowed access at all.

S. Determine level of personal protective equipment required.

T. Establish plan to track personnel: personnel should have one location of entrance and exit for the site, and have a court admissible log of who went where when. This is important for the security of the site, for chain of custody, and for the validity of evidence collected.

U. Obtain city utility maps (gas lines, electrical lines, etc.) and compile in a GIS program.

V. Select a budget officer for the recovery effort.

W. Discuss and determine regular meeting times.

X. Emphasize the importance of communication and teamwork.

Part 3. Implementation of Recovery Plan: Preparation for Scene Documentation and Victim Recovery operation.

Following final planning and protocol and procedure determination, preparation for the full-scale scene recovery can begin. The first step is to clearly define scene boundaries, establish badging procedures, set up work, supply, first aid, food, and rest stations. Procedures and tasks to be completed during this site visit include, but not restricted to:

A. *Create Scene Boundaries.*

Level 1. Establish main entrance and exit to the general scene (at a distance from the site to avoid contact with media and citizens). The boundary should be established at a location without material from the disaster, as well as at a location far enough away to keep unwanted media and bystanders out of the site.

Level 2. Establish entrance and exit to immediate recovery scene (only excavators and scene recovery personnel permitted). Entrance to each scene level requires a badge, barcoded and scanned.

B. *Establish a Badging Location* (off site though best near the entrance of the site) for the creation of identification badges and level of security. Use unique barcodes with each name for ease of site personnel logs.

C. *Determine Meeting Location(s)* and *Schedule Daily Briefings*: Meet at beginning and end of each day to discuss objectives.

D. *Establish Rest and Refreshment areas*. Designate times for groups to take breaks and get refreshments.

E. *Establish a Central Command Center* for information and data collection, including GIS (Appendix 1: Figure 12).

F. *Establish Screening Station location.* Pick a location beyond the immediate crash site but not too far away so that transporting debris is difficult and slows the process.

G. *Establish First Aid Center*.

H. *Establish Supply Center*.

I. *Establish Restroom Facilities*.

J. *Establish Decontamination Station* at entrance/exit to the immediate crash site.

K. *Establish Dressing Center* supplied with Personal Protective Equipment (PPE) and scene recovery tools and equipment.

Section 3. Excavation, Documentation and Recovery Protocols

Part 1. Preparation for Excavation

Evaluate the crash site once it has been cleared for safety: Prior to finalizing recovery protocols, each site must be evaluated for unique circumstances. The following points should be evaluated initially, and then again daily to account for weather changes, different areas needing different techniques, and any other changes in circumstance throughout the processing of the scene.

A. Initial Briefing of Excavators

B. Present the final plan for site documentation, body recovery, and body transportation.

1. Total station and/or survey-grad GPS and 3D mapping procedures (see Appendix 5 for configurations).
2. Optimized screening procedures.

C. Environmental conditions: Weather forecasts must be consulted in advance, and again daily, to best prepare recovery personnel.

D. Issue badges to personnel to enter the site through previously determined badging site.

E. Maintain daily rosters and timed work logs.

F. Establish break-taking protocols for personnel.

G. Schedule meal and break times for personnel groups in order to maximize efficiency.

H. Reaffirm the primary goals of the recovery of human remains and physical evidence.

Priority 1. Locate, document and recover the maximum number of *human remains* without commingling and disassociation by conducting an effective and efficient location and recovery strategy.

Priority 2. Locate, document and recover *personal effects* taking care to note their spatial context to biological remains.

Priority 3. Document the scene in order to obtain as much *contextual evidence* from the scene as is necessary in order to aid in the investigation and reconstruct past events. Documentation must include written notes, photographs of the scene recovery process and evidentiary items *in situ,* videos, and detailed mapping procedures.

Excavation Protocols

Two sets of protocols will be discussed. The first one will concern a highly dispersed mass fatality scene (often encompassing acres of land). The second concerns a condensed event such as an *in situ* burning or a slower speed crash such as Colgan/Continental Flight 3407 crash in Clarence Center, NY.

Part 2. Search and Recovery Protocols for Highly Dispersed Mass Fatality Event

Principle. Search and recovery protocols encompass the location, documentation, and collection of human remains, personal effects and any other evidence (such as critical dials and switches from the plane cockpit) deemed significant at the incident site (termed here, *Significant Evidence*). The primary goals of the recovery operation will be to: 1) systematically and thoroughly locate all Significant Evidence and 2) document the precise location of the Significant Evidence *in situ* and in three dimensions. Finally, the Significant Evidence is recovered and removed from the scene without further alteration or damage. Following these protocols will establish chain of custody early and ensure maximal recovery of significant evidence.

Phase 1. Documenting the Scene of Recovery of Significant Evidence

Personnel. Excavation Team including: Scene Manager, Search Team, Photography Team, Videography Team, Provenience Team, Collection Team, Debris Removal Team, Narrative Team, Intake Team, C/ME.

Procedure. The recovery operation will be organized such that all documentation/recovery teams operate within an interdigitated, structured, and properly sequenced plan. Workers will report to the staging area at the beginning of the work day where a briefing will be held by the scene manager to review the recovery plan for that day, issue work assignments, and divide workers into Recovery Teams based on roles and responsibilities (See Appendix 2 and 3 for teams and necessary equipment). Individual teams will be assigned to a particular recovery area (within previously defined corridor) and will work independently from other such teams and at their own pace. The recovery plan will then be put into place. The Scene Manager will monitor work progress and adjust recovery operation accordingly.

Step 1: Initial Documentation. The initial documentation of the site (prior to recovery) will include written descriptions of the scene and context, photographic documentation, and videographic documentation (Appendix 1: Figures 13 and 14).

A. *Narrative Team* begins Incident Narrative (IN) of recovery, which includes:

1. General description of location, surrounding environment, weather, etc.
2. Record of personnel, activities, and timeline of events during recovery.
3. Update IN at least every 15 minutes.
4. Best to use standardized digital forms (see Appendix 5 for examples of forms) on ruggedized computers on-site.

B. *Photography Team* begins general scene photodocumentation (Appendix1: Figures 15-16)

1. Digital imaging will work best.
2. Photographic images of general views of the scene from cardinal directions (E, W, N, S).
3. Detailed shots of the scene and items of interest (from outside of the scene).
4. Detailed log (hand written or electronic) of all photographs taken will be kept and will include information on what is of interest in the shot and direction and orientation of the shot (Appendix 6).

C. *Videography Team* begins general scene documentation (Appendix 1: Figure 17).

1. Set up video camera at a spot where the majority of the scene can be viewed.
2. Videotape (slow pan) the scene and surrounding area with the sound muted.
3. Camera can be moved to different vantage points.
4. Video log (hand written or electronic) must be kept.

Step 2: Preparing the Scene for Recovery. Provenience Team establishes a corridor system in which a series of parallel or near parallel corridors approximately 30 ft (10m) in width, large enough to accommodate 15-20 line searchers, is demarcated over the primary site (Appendix 1: Figures 18 and 19).

A. In open areas (no trees), corridors can be established more precisely with total station/survey-grade GPS, or by hand by running crime scene tape to stakes. with tape measurers. Wooden stakes/metal rebar are placed in the ground (at least 3 ft tall) and sprayed with neon spray paint. Crime scene tape is used to demarcate the boundaries of the corridors.

B. In forested areas, corridors can be established by running crime scene tape between trees (and mapped in later with total station or survey grade GPS).

Step 3: Establish Primary Site Datum. Provenience Team establishes a primary datum for the scene. The datum should be as close to permanent as possible (Appendix 1: Figures 20 and 21). Exacting GPS coordinates must be taken. Instructions for establishment of the datum can be found in the Appendix 7.

Step 4: Search Team. Search team assembles at one end where there is little to no evidence and begins a slow, shoulder-to-shoulder, systematic pedestrian search through the corridor until the other end is reached and no further evidence found.

A. Identify a Search Team Leader to maintain pace and search line and to stop search when necessary (Appendix 1: Figures 22 and 23).

B. Search Team members flag Significant Evidence only, placing the flag in a predetermined, standardized location for all evidence (e.g., southwest corner of Significant Evidence). Different color flags can be used for different types of evidence. Evidence should not be disturbed (Appendix 1: Figures 24 and 25).

Step 5: Provenience Team. Provenience team follows behind search team and records spatial data for all Significant Evidence (human remains, identifiable plane parts, and personal effects) (Appendix 1: Figure 26).

A. Provenience team evaluates the forensic significance of each item and records the coordinate point.

B. Barcode Labeler affixes unique, pre-printed barcode on the flag (Appendix 1: Figures 27-28)

C. Barcode Machine Operator scans the barcode, relays the information to the GPS operator via walkie-talkie, and enters a brief description of the evidence in the barcode database (Appendix 1: Figures 27 and 28).

Step 6: Significant Evidence Photography Team

A. Photography Team Scribe lays scale, north arrow, and pin flag with visible barcode on ground near evidence (Appendix 1: Figures 29 and 30).

B. Photograph is taken perpendicular to the ground. Multiple photographs should be taken.

C. Photography Team Barcode Machine Operator scans barcode and includes brief description of photograph contents and photo number.

D. Photography Team will mark an “X” on the back of the flag (avoiding the barcode) to denote that the item is ready for collection and put flag back in ground in approximately the same location.

Step 7: Evidence Collection Team. Collects Significant Evidence from scene for transport to Intake Station (Appendix 1: Figure 31).

A. Smaller items placed in labeled zip-lock bags. Larger evidence placed in other labeled containers (Appendix 1: Figures 32 and 33).

B. Remove flag with barcode and put inside evidence bag (all barcodes should be waterproof).

C. Duplicate barcodes must be placed on outside of bag.

D. Runners remove evidence from scene and take to Intake Station.

Step 8: Intake Team. Significant Evidence is brought to intake station. Each collection bag is scanned and entered into the data log to record time and date of entry (Appendix 1: Figure 34 and 35).

A. Significant Evidence is prepared for transport off-site (e.g., human remains to disaster morgue).

Phase 2. Comprehensive Debris Removal Effort. After all corridors on the scene are processed and all reasonable efforts to collect all Significant Evidence are completed, the scene is re-searched multiple times with forensic professionals present, and *all* remaining debris on the scene is removed (Appendix 1: Figures 37, 38 and 39).

A. Debris is collected without data collection via hands-and-knees search.

B.Any remaining Significant Evidence that is found will be properly documented (provenienced, photographed, logged) and collected.

C. This step can be repeated numerous times.

Summary. Dividing the crash site into manageable corridors allows for a rapid processing and documentation of the scene. Proper documentation, complete with adequate contextual information not only will aid in the reconstruction of the death event, but also allow for the future refinement of the collection protocols and in future preparedness training. The biggest lag in the recovery process is generally due to the Photography Team. The inclusion of two Photography Teams for each Provenience Team keeps the entire process streamlined. Also, each team using barcode machines allows for complete asset tracking from the field to the lab. This, again, will aid in the reconstruction of the scene by allowing for the tracking of a particular artifact to its original location post-crash.

Search and Recovery Protocols for a Condensed Mass Fatality Event

Principle. General recovery considerations for contained mass fatality scenes (i.e., a dense concentration of crash debris that is limited in spatial distribution, usually through a low velocity impact; e.g., a crash site in a residential area, such as the Colgan/Continental Connection Flight 3407 crash) require recovery protocols different than those applicable to crash sites involving widely scattered debris fields. Due to the concentration of Significant Evidence in debris piles in these events, scene search protocols (described in the Dispersed Scene protocols) will be restricted to areas beyond the debris pile. The recovery protocols for processing the debris pile will focus on the employment of proper archaeological excavation techniques. The Provenience and Photography Teams will largely follow the same protocols as described in the large-scale dispersed scenarios.

Personnel. Excavation Team including: Scene Manager, Photography Team, Videography Team, Excavation Team, Provenience Team, Collection Team, Debris Removal Team Search Team, Written Narrative Team, Intake Team.

Procedure. The recovery process will entail the detailed search for Significant Evidence beyond the crash debris concentration, as well as the excavation, documentation and recovery of Significant Evidence found within the crash debris concentration. *The primary goals are to note the precise position and orientation of all Significant Evidence, especially human remains, and to recovery this evidence without any further alteration and damage*.

Phase 1: Initial Documentation. The initial documentation of the site (prior to recovery) will include written descriptions of the scene and context, photographic documentation, and videographic documentation.

A. *Narrative Team* begins Incident Narrative (IN) of recovery, which includes (Appendix 1: Figures 13 and 14):

1. General description of location, surrounding environment, weather, etc.
2. Record of personnel, activities, and timeline of events during recovery.
3. Update IN at least every 15 minutes.
4. Best to use standardized digital forms (see Appendix 6 for examples of forms) on ruggedized computers on-site.

B. *Photography Team* begins general scene photodocumentation (Appendix 1: Figures 15 and 16).

1. Digital imaging will work best.
2. Photographic images of general views of the scene from all cardinal directions (E, W, N, S).
3. Detailed shots of the scene and items of interest (from outside of the scene).
    a. Detailed log (hand written or electronic) of all photographs taken will be kept.

C. Videography Team begins general scene documentation. Set up video camera at a spot where the majority of the scene can be viewed (Appendix 1: Figure 17).

1. Videotape (slow pan) the scene and surrounding area with the sound muted.
2. Video camera can be moved to different vantage points for different scene perspectives.
3. Video log (hand written or electronic) must be kept.

D. Provenience Team (Large Scale) begins large-scale survey of the scene (including nearby roads, houses, trees, etc.). Multiple Provenience Teams can be working concurrently (Appendix 1: Figures 20 and 21).

1. Establish a scene datum (Appendix 7).
2. Map in major features of the scene.
3. Every two hours hereafter in, record the boundaries of the debris pile in order to track the progress of the excavation (Appendix 1: Figure 40).

Phase 2. Search of the Surrounding Scene (Beyond the Condensed Crash Debris)

Search Teams conduct straight-line pedestrian searches of the surrounding areas. Corridors may be established to more clearly define search parameters in a rural setting. In an urban/suburban setting, streets and yards can be used to subdivide the site. Once the areas beyond the immediate scene are searched with any Significant Evidence provenienced, noted and removed (using the same high resolution techniques as in the Dispersed Crash Site Protocols), attention can be focused on the crash debris concentration (Appendix 1: Figures 24 and 25).

Phase 3. Excavation.

The Excavation Team will begin the recovery process excavation by removing debris from the edges of the debris pile. *The primary goal is to locate, fully expose, document the location, position and orientation (i.e., provenience the remains), and carefully remove all human remains in a systematic manner. Additionally, all other Significant Evidence (personal effects, significant aircraft parts) will be located, documented and removed systematically*.

Once all personal effects have been collected and removed from the initial crash site, they will be released to the Contracted Personal Effects Company or designated agency in preparation for return to the family.

Personnel. Scene Manager, Forensic Archaeologists, C/ME personnel, FBI ERT, NTSB, Firefighters.

Procedure.

Step 1. Pre-excavation briefing with Scene Manager.

A. Brief Excavation Team members on details of the recovery protocols, define Significant Evidence (SE) and what should be provenienced, where to get first aid and supplies, mandatory break taking procedures, and assigning shifts. Permit question and answer session and then finalize protocols relative to current scene conditions and circumstances.

B. Assign members to individual Recovery Teams. Volunteers without training in identifying human tissue will be interdigitated with Forensic Archaeologists (one Forensic Archaeologist for every two untrained volunteers).

Step 2. Excavation Team. The Scene Manager will determine the best recovery excavation procedure based on the scene and debris pile characteristics. In most cases, this will include lining up excavators at the edges of the debris pile and removing matrix from the top of the debris pile and working downward until the bare substrate is reached (top-down method) to reveal a near vertical excavation face. Excavation proceeds inward toward the center of the debris pile.

A. Begin excavation around perimeter or edge of debris field.

B. Excavation methodology focuses on 'Top-Down' method of debris removal to create a vertical face.

C. Debris that is not to be provenienced will be removed from the debris field and placed behind excavators in preparation for removal.

D. When human remains are encountered, all debris is removed from atop the tissue.

E. Human remains and other SE are provenienced, photographed and eventually removed only after being completely exposed from the debris pile. ***Remains are considered fully exposed when they can be lifted straight up, in one piece, from the surrounding debris pile.***

F. Small, unrecognizable, disassociated pieces of human tissue are placed in the Common Tissue bin as they are encountered (Appendix 1: Figure 41).

G. Pin flags are placed next to the remains to indicate that they are ready for the provenience notation by the Provenience Team and photographic documentation by the Photography Team.

Step 3. Debris Removal Team. Debris Removal Team will place excavated debris into containers to be taken either off-site or to the screening stations. This debris can be sorted into unique piles if desired. Non-Significant Evidence that is too large to be screened can be disposed of in dumpsters. *All ash, dirt, and other small debris should be screened.*

Step 4. Screening Team. All loose debris (dirt, ash, etc.) transported by the Debris Removal Team to the screening stations will be screened via 1/4" mesh screens. *Each Screening Team should have at least one Forensic Anthropologist for every two screens* (Appendix 1: Figure 42).

A. Record date and time of each piece of Significant Evidence found on the screen.

B. Any Significant Evidence found on the screen should be photographed on the screen and follow protocols for documentation (photographing, barcoding).

Step 5. Significant Evidence Provenience Team. The Provenience Team uses a Total Station or survey-grade GPS to note the location of *all* Significant Evidence (Appendix 1: Figure 43).

A. After the human remains are fully exposed, the Provenience team records enough coordinate points to define the position and orientation of the body or body part. This should minimally include recordation of all available major limb joints (See Appendix 4 on number of points/naming points).

B. Personal Effects and other Significant Evidence are piece-plotted (one point per item).

C. Barcode Labeler affixes unique, pre-printed barcode to the pin flag.

D. Barcode Machine Operator scans the barcode, relays the information to the GPS operator via walkie-talkie, and enters a brief description of the evidence in the barcode database.

E. The Large Scale Provenience Team will record the extent of the debris pile every two hours to track progress.

Step 6: Evidence Photography Team. The Photography Team will take multiple pictures of all Significant Evidence.

A. If necessary, outline the remains with brightly colored string if the position and orientation of the body or body part is not clear (e.g., in burned situations).

B. Photography Team prepares each photograph with scale, north arrow, and assigned barcode (Appendix 1: Figures 29 and 30).

C. Photographs are taken perpendicularly to the ground, if possible.

D. Multiple photographs should be taken with various settings (bracketing up and down one f-stop, as well as with and without flash) to ensure at least one high quality image.

E. The Photographer will dictate pertinent information concerning the photograph to the Photographic Log Scribe, including range, brief description and photograph filenames (e.g., img.244- img249).

F. The photographic log scribe will also use a handheld barcode machine to record the barcode along with information dictated by the photographer.

G. Photography Team will mark an “X” on the back of the flag (avoiding the barcode) to denote that the item is ready for collection and put flag back in ground in approximately the same location.

Step 7. Narrative Team. Written descriptions via the Incident Narrative of the position and orientation of the remains are recorded using standardized forms.

A. Update IN with personnel and roles within the site (every 15 minutes).

Step 8. Evidence Removal Team. Once human remains have been *sufficiently documented*, they must be prepared for removal from the debris pile.

A. If remains are relatively fragile from burning or impact, wrap the heads, hands and other fragile elements with heavy duty plastic wrap to negate any further deleterious post-mortem change to the remains (Appendix 1: Figure 44).

B. Remove body by picking it straight up off of the debris pile and place it into a proper container (e.g., body bag, plastic zip-top bag).

C. Place flag with barcode in with the remains.

D. The Barcode Labeler will affix a corresponding barcode on the outside of the body bag.

E. Body is taken to an on-site holding area prior to transportation to the morgue.

F. Relevant agencies will collect the evidence falling within their jurisdiction, following the roles and responsabilities discussed before the commencement of the search and recovery operations.

Summary. Proper archaeological excavation is paramount in the recovery of a confined mass fatality event. Using the methods detailed above, all of the recoverable Significant Evidence, including human remains, will be located and fully documented *in situ.* The proper documentation of the human remains, including a sufficient number of provenience points to understand the position and orientation of the victim, will aid in reconstruction of past events, as well as a means to understand patterns and dynamics of a mass fatality event to refine the protocols for future deployment. The inclusion of barcoding technologies allows for each piece of evidence to be tracked from the field to the morgue, thus establishing the chain of custody.

Appendix 1

Figures 1 and 2. Agency representatives making an initial assessment of the scene.

Figure 3. Entrance/exit locations at scene, including places at which to rid clothing of hazardous materials.

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Figure 4, 5 and 6. Initial briefing of scene to representatives and presentation of recovery plan.

Figures 7 and 8. Initial briefing of excavators.

Figures 9 and 10. Locations of Command Center and Disaster Morgue.

Figure 11. Aerial view of a scene.

Figure 12. Command center.

Figures 13 and 14. Narrative team extensively documents activities of all personnel, through the use of a toughbook, during the entirety of the recovery process.

Left: Figure 15. Photographic documentation of the scene.

Right: Figure 16. Photographer and photographic logger begin scene documentation.

Figure 17. Videocamera set up in location to view entire scene.

Figures 18 and 19. Provenience Team establishing a corridor system.

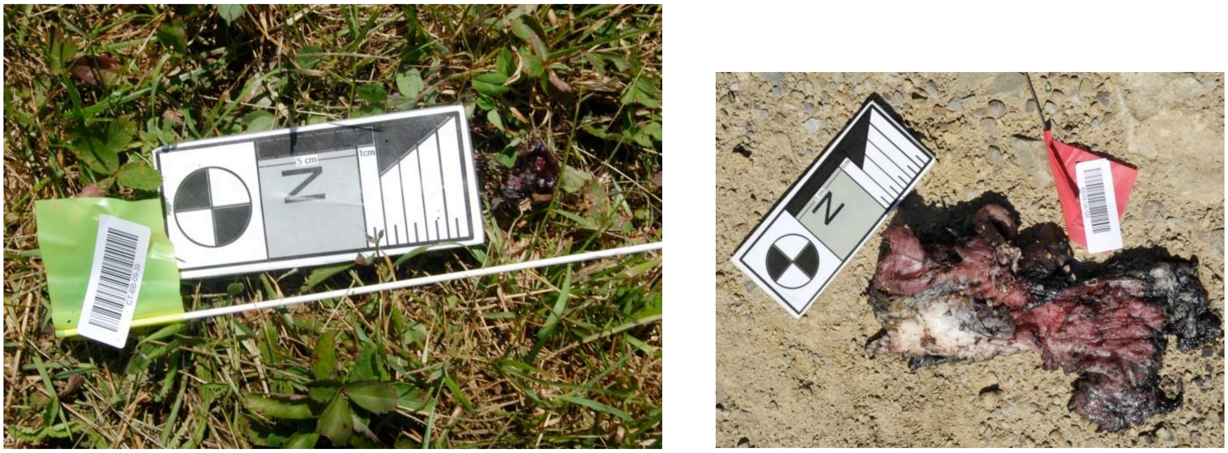
Figure 20 and 21. Establishing primary site datum (left). Total station assembled at the edge of the scene (right).

Figure 22 and 23. Search Team Leader instructing the searchers on what to flag as significant.

Figures 24 and 25. Searchers in a line search looking for significant items.

Figure 26. Provenience Team (far left of photo) follows behind the Search team.

Figures 27 and 28. Barcode Labeler affixes a pre-printed barcode (seen above) on each flag and BMO scans the barcode (left).



Figures 29 and 30. Photography Team photographs scale, north arrow, and pin flag with visible bar code.

Figure 31. Evidence Collection team.

Figures 32 and 33. Items should be placed in a zip-lock bag with the flag.

Figures 34 and 35. All items brought to the Intake station are documented and sorted.

Figure 37. Non-forensic professionals search the scene multiple times, aided by forensic specialists.

Figures 38 and 39. All debris is removed from scene.

Figure 40. Extent of debris pile is marked with flags and provenienced every two hours.

Figure 41. Unrecognizable, disassociated pieces of human tissue are placed in the Common Tissue bin.

Figure 42. Screening Teams sifting through all dirt and ash.

Figure 43. Provenience Team documenting spatial location of each piece of Significant Evidence.

Figure 44. Fragile areas are wrapped in heavy-duty plastic wrap to minimize fragmentation and evidence loss.

Appendix 2

Individual Scene Recovery Teams: Components, Roles and Duties

A. **Scene Manager**: The Scene Manager will be responsible for the day-to-day operations of the recovery and excavation. The Scene Manager will construct and enforce the recovery plan, as well as revise it, if necessary. The most qualified person to fill this position would be a board Certified Forensic Anthropologist with previous experience in forensic archaeology and mass fatality situations. She will also manage communication between the field and the morgue.

1. **Responsibilities.**
    a. Devise, maintain and update recovery plan.
    b. Manage overall scene.
    c. Act as liaison between periphery agencies and C/ME.

B. **Written Narrative Team**: The Written Narrative Team plays a pivotal role in the comprehensive documentation of the crash site, as well as the proceedings.

1. **Primary Personnel**. Incident Narrative Scribe/Notetaker and Assistant.
2. **Responsibilities**. Complete written documentation of scene recovery that is entered into a computer database including:
    a. Details of site location (county, township, nearby towns, etc.).
    b. Names, addresses, and rank of all individuals on the scene.
    c. Scene description (total vs. partial structure burn, etc.).
    d. Description of crash site.
    e. Time-stamped, sequential description of all activities and personnel, at least every 15 minutes.
    f. Description of weather conditions.

C. **Photography Team**. The Photography Team is responsible for photo-documentation of each piece of evidence. The photographer follows the same sequence behind the the Provenience Team allowing for a streamlined documentation process.

1. **Primary Personnel**. Photographer and Photographic Log Notetaker/Scribe.
2. **Responsibilities.**
    a. General views of the scene from all 4 cardinal directions.
    b. General views of interesting features.
    c. Photograph recovery process.
    d. Photograph evidence in situ with scale, north arrow, and barcoded flag.
    e. Photography log using a handheld barcode machine to record barcode number, as well as information concerning each photograph with each piece of evidence.

D. **Videography Team.** The Videography Team is responsible for the videographic documentation of the initial scene, as well as the duration of the recovery effort.

1. **Primary Personnel.** Videographer and Assistant.

2. **Responsibilities**.
   - a. Videodocument general views of the scene.
   - b. Videographic documentation of recovery process.
   - c. Videotape evidence in situ.
   - d. Videotape human remains in situ.

E. **Provenience Team**. The Provenience Team should be composed of individuals experienced in using Total Stations and GPS machines, as well as a basic understanding of the effective documentation of human remains to preserve the position and orientation of *Significant Evidence*. Depending on the circumstances of the crash, the Provenience Team might also determine the significance of evidence.

1. Primary Personnel. Total Station Operator and Assistant (communicating with Prism Operator via walkie-talkie and operating the handheld computer), Prism Team (Prism Operator and Assistant), GPS Operator (if survey-grade GPS is used, a Total Station will not be necessary), Barcode Team (Barcode Machine Operator and Barcode Labeler to work with the Prism Operator or Survey-Grade GPS Operator).

2.**Responsibilities for Total Station configuration**.
   - a. Prism Operator and Barcode Team determine whether flagged item is *Significant Evidence*.
   - b. Barcode Labeler assigns significant evidentiary items, including human remains, a barcode placed on the flag demarcating the item.
   - c. Prism Operator places prism near *Significant Evidence* making sure the prism is level.
   - d. Total Station Operator sites the prism.
   - e. Total Station Assistant collects the point.
   - f. For larger objects, record enough points to determine the outline of the shape. For intact human remains, record points at major joints to retain the position and context of the remains.
   - g. Total Station Assistant communicates with Prism Team via walkie-talkie to record the barcode number and class of evidence.
   - h. Barcode Labeler removes flag from standing position and lays it on the ground to signal that it has been provenienced.

3.**Responsibilities for Survey-Grade GPS configuration**.

a. GPS Operator and Barcode Team determine whether flagged item is *Significant Evidence*.
b. Barcode Labeler assigns significant evidentiary items, including human remains, a barcode placed on the flag demarcating the item.
c. Prism Operator places prism near *Significant Evidence* making sure the prism is level.
d. GPS Operator places GPS unit near the item and collects the point.
e. For larger objects, record enough points to determine the outline of the shape. For intact human remains, record points at major joints to retain the position and context of the remains.
f. GPS Operator records the barcode number and class of evidence. .
g. Barcode Labeler removes flag from standing position and lays it on the ground to signal that it has been provenienced.

F. **Search Team**: The Search Team will be composed of 'Searchers' who will systematically survey a corridor noting the presence of any *Significant Evidence* with pin flags, but not moving it. The Search Team should be composed of personnel with diverse expertise to ensure that all the different types of Significant Evidence (human remains, significant vehicle parts, potential bomb parts) are located and properly identified.

1. **Primary Personnel.** Forensic Anthropologists and relevant agencies (e.g. NTSB and FBI)
2. **Responsibilities.**
    a. Shoulder-to-shoulder pedestrian straight line search of each corridor.
    b. Flag all relevant evidentiary items including human remains.
    c. Do not disturb provenience of all evidence.

G. **Excavation Team**: The Excavation Team will be composed of 'Excavators' who will systematically and carefully remove debris from the debris pile to expose Significant Evidence. Trained Forensic Anthropologists/Archaeologists must assume an enhanced role here because of their experiences with altered (burned, decomposed and fragmented) and unaltered human tissue. Other excavators can include volunteers in law enforcement, C/ME personnel, fire fighters, and other willing professionals.

1. **Primary Personnel**. Forensic Archaeologists, FBI ERT, C/ME personnel, Firefighters.
2. **Responsibilities.**
    a. Use proper archaeological excavation techniques to excavate, expose and document Significant Evidence, including human remains.

  b. Excavate from the outer extent of the debris pile and work inwards while on hands and knees.
  c. Retain the provenience of the item.

H. **Collection Team**. The Collection Team is the last link between the field and the morgue. Through this, it is important to double check the corresponding numbers for the piece of Significant Evidence, and the duplicate placed on the outside of the proper container.

1. **Primary Personnel**. Evidence Collector, Barcode Machine Operator, Evidence Bag Labeler.
2. **Responsibilities.**
   a. Evidence collector clips the flag with marked barcode and place inside bag with evidence.
   b. Evidence bag labeler will affix a duplicate barcode on outside of bag.
   c. Barcode machine operator will scan barcode and record date and time of collection, type of evidence (tissue, personal effect, etc.), and name of collector.
   d. Evidence is moved to bins to be brought to storage/intake station.

I. **Intake Team.** The Intake Team is responsible for the collection of *Significant Evidence* into short-term storage before it is transported to the disaster morgue.

1. **Primary Personnel.** Barcode Machine Operator and Assistant.
2. **Responsibilities.**
   a. Barcode Machine Operator scans the barcode of the incoming evidence.
   b. The Assistant transports the scanned evidence into refrigerated truck or holding area.

J. **Debris Removal Team**. The Debris Removal Team plays an integral role in keeping the excavation on track. They will double as ‘runners’ on the scene for the various teams.

1. **Primary Personnel**. Firefighters.
2. **Responsibilities.**
   a. Removal of large debris by means of heavy machinery under supervision of team leaders.
   b. Constantly bringing bins of excavated material to the Screening Team(s) and returning an empty bin to the Excavation Team(s).
   c. Removal of searched debris from the scene.
   d. Act as ‘runners’ for excavators (e.g., retrieving new equipment).

K. **Screening Team**: The Screening Team will be composed will hand sort all of the loose debris to find any additional Significant Evidence. Ideally, there should be at least one Forensic

Anthropologist for every two Screening Teams. The Forensic Anthropologist can answer any questions by another member.

1. **Primary Personnel.** Forensic Anthropologists and trained members of other relevant agencies (e.g. NTSB, FBI ERT, C/ME Office).

2. **Responsibilities.**

    a. Screen excavated debris.

    b. Identify human remains and other evidentiary items.

Appendix 3

Basic Recovery Team Equipment Lists

A. **Written Narrative Team**.

1. Basic configuration.
    a. Incident Narrative form.
2. Advanced configuration.
    a. *Toughbook* ruggedized laptop.

B. **Photography Team**.

1. Basic configuration.
    a. DSLR camera.
    b. Photographic logbook.
2. Advanced configuration.
    a. DSLR camera.
    b. Handheld computer/barcode machine.

C. **Videography Team.**

1. Basic Configuration.
    a. Video camera.
2. Advanced configuration.
    a. High-definition digital video camera.

D**. Provenience Team**.

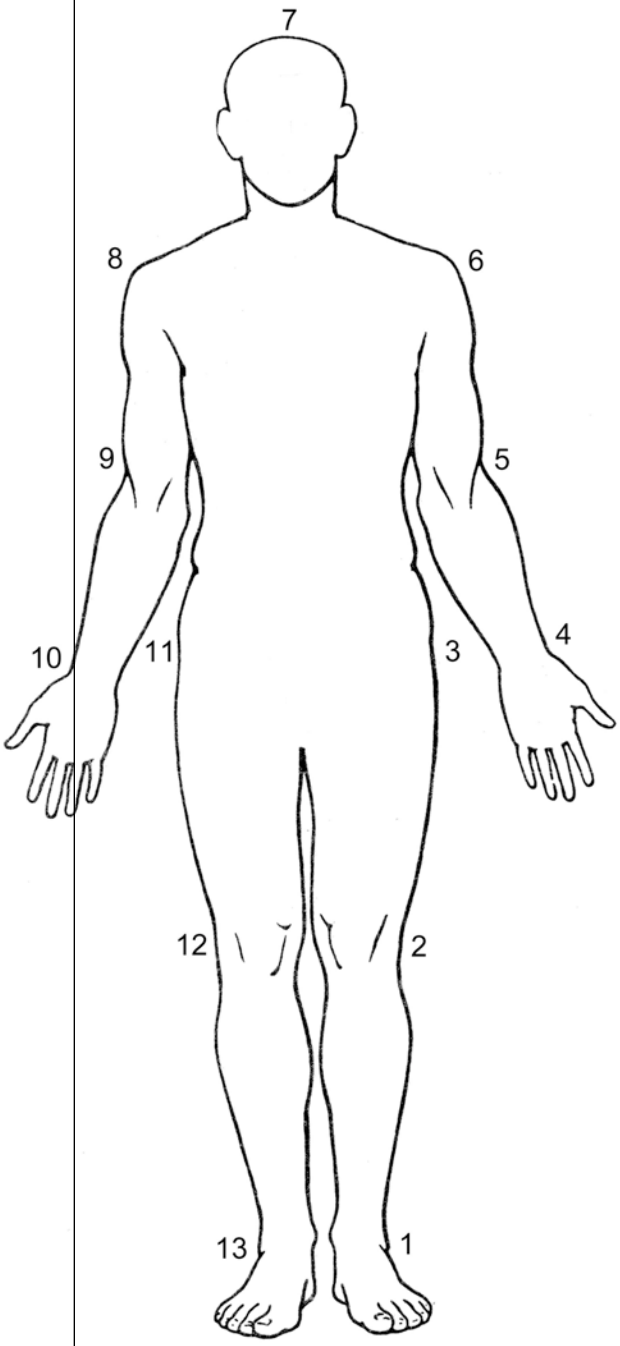
1. Basic configuration.
    a. Electronic total station with prism and standard GPS machine.
    b. Walkie-talkies
2. Advanced configurations.
    a. Robotic total station with GPS machine.
    b. Survey-grade GPS machine.

D. Excavation Team.

1. Leather, steel-toed boots.
2. Leather working gloves.
3. Latex gloves.
4. Tyvek suits.
5. Face masks.
6. Trowels.
7. Dust pans.

Appendix 4

Provenience Numbering



It is important to have a consistent numbering scheme when documenting intact human remains. This allows for a consistent representation of spatial orientation of the remains. The figure on the left is a suggested numbering scheme comprised of 13 points. This will detail all of the major articulating joints of the body, as well as the apex of the skull. This will allow for the recordation of the general body orientation prior to removal. In the occurrence of disarticulated tissues, it is ideal to record any identifiable joint and the longitudinal apices of that specific piece. If no joints are available, or the tissue is unrecognizable, a single provenience point will suffice.

Point	*Joint*
1	Left Ankle
2	Left Knee
3	Left Hip
4	Left Wrist
5	Left Elbow
6	Left Shoulder
7	Apex of Skull
8	Right Shoulder
9	Right Elbow
10	Right Wrist
11	Right Hip
12	Right Knee
13	Right Ankle

Appendix 5

Provenience Team Configurations

A. Configuration 1: Total Station and traditional GPS

1. The total stations should be located in an area of highest elevation and maximum visibility of the scene, or the corridor to be searched.
2. Discuss total station protocols with Collection and Photography Teams to ensure a consistent artifact numbering system.
    a. The total station number should match the bar code number or the number on the human remains.
3. Ensure that each total station or GPS are using the same units of measurement (metric or standard) and the same geographic coordinate system.
4. Multiple Total stations can be used (maps later linked by spider mapping).
    1. Linking multiple total stations requires at least 3 common points.
5. Establish how many total station points will be taken for larger human remains fragments: outline or points at each major joint. For more complete remains, it is necessary to collect enough points to document the position and orientation of the body. This should minimally include all of the major joints.
6. Assign three individuals to operate the total station.
7. At the Total Station:
    a. Two individuals can work together to efficiently and rapidly take points and communicate with the prism operator via walkie-talkie.
    b. One individual can use the site to find the prism while the other individual is communicating with the prism holder, taking the point on the data recorder and recording the points in a logbook.
    c. The third individual holds the prism and communicates the barcode number or human remain number to the total station operators via walkie talkie.
8. Assign 2 individuals to operate a GPS.
    1. One person operates the GPS while the other person records a log of points and can assist the operator.
    2. The GPS must take at least four points in common with the total station including the datum and backsight.

B. Configuration 2: Survey-grade GPS.

1. The survey-grade GPS effectively takes the place of a total station and traditional GPS.
2. Select appropriate geographic datum and coordinate system: It is important that the appropriate datum and coordinate system are used in conjunction with geo-referencing. All coordinate systems are based on a datum. This is because coordinate systems are based on approximations of the earth's shape. North America has two specific datums (North American Datum, or NAD), the NAD1927 and an updated NAD1983. Using the NAD1983, each state has had specific coordinate systems designed for accurate mapping. These are known as the State Plane systems. It is recommended that the correct 'State Plane' system is utilized using the NAD1983 datum. The appropriate State Plane system can achieve accuracy of 1:10,000 of an inch. Collecting data in one coordinate system, such as the NAD1927 and comparing it to data collected in NAD1983 can produce errors as great as 200 meters in the N-S direction, and 70 meters in the E-W direction. This is known as the NAD Shift and acts as a reminder to be cognizant of the coordinate systems being employed.
3. One person operates the machine by placing it level at the item of interest and a second person assists by keeping a written log of points collected.
4. Discuss provenience protocols with Photography and Collection Teams.
    a. Using consistent numbering systems for evidence recorded.
5. Discuss number of points taken for human remains and larger debris.

FORENSIC ANTHROPOLOGY AT MERCYHURST COLLEGE

Appendix 6

Incident Narrative At Crime Scene

Recorder:________________________________ Date:_________________

Time of Arrival: _________________ Time of Departure:________________

Case #:_____________________ **Agency:** ____________________________

Location: State:______ County:__________________ Township:__________________

Address/Street/Road:____
____
____
____

Reference materials and coordinates:

☐ Topographic map used: ____

☐ Latitude and longitude:___________ ☐ UTM Coordinates: ______________

☐ Aerial Photographs:______________ ☐ Elevation: ____________________

Scene Type:

☐ Surface Scatter ☐ Completely Buried ☐Partially Buried ☐ Fire Scene

☐ Mass Fatality ☐ Indoor Scene

Inside (Check all that apply) Outside

☐ House/apartment
☐ Bathroom
☐ Basement
☐ Attic
☐ Bedroom

☐ Business
☐ Storage Unit
☐ Living room
☐ Kitchen
☐ Garage

☐ Field
☐ Woods
☐ Beach
☐ Ditch
☐ Pavement

☐ Pasture
☐ Brush
☐ Lake/Pond
☐ River/Stream
☐ Swamp

☐ Along country road/remote
☐ Along highway/busy

☐Other____

Brief Description (give a brief description of scene at arrival)

____
____
____
____
____
____

Agencies/organizations involved

☐ County Law Enforcement	Lead__________________________
☐ State Law Enforcement	Lead__________________________
☐ FBI	Lead __________________________
☐ Coroner	Lead __________________________
☐ District Attorney	Lead __________________________
☐ Fire/Rescue	Lead __________________________
☐ Other ________________________	Name__________________________
☐ Other_________________________	Name__________________________

Additional comments/notes:

____
____
____
____
____

Name	Agency/Institution	Address	Phone and Fax

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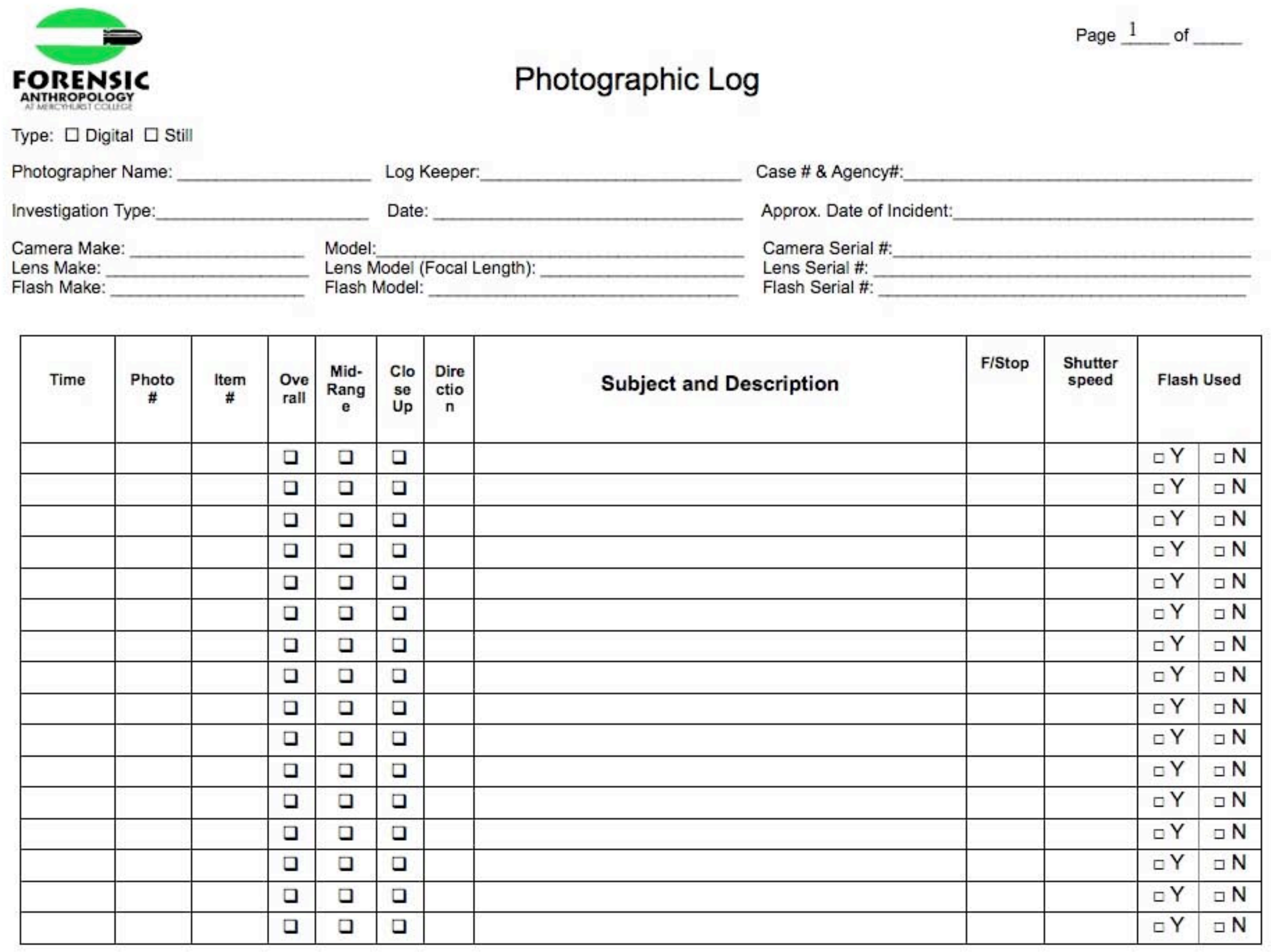
AT MERCYHURST COLLEGE

Name of Recorder:__________________________ Location:______________________________

Case #:___________________ Agency #:____________________ Date:____________________

Time	Weather	Temp.	Description of proceedings



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Photographic Log

Type: ☐ Digital ☐ Still

Photographer Name: ____________ Log Keeper: ____________ Case # & Agency#: ____________

Investigation Type: ____________ Date: ____________ Approx. Date of Incident: ____________

Camera Make: ____________ Model: ____________ Camera Serial #: ____________
Lens Make: ____________ Lens Model (Focal Length): ____________ Lens Serial #: ____________
Flash Make: ____________ Flash Model: ____________ Flash Serial #: ____________

Time	Photo #	Item #	Overall	Mid-Range	Close Up	Direction	Subject and Description	F/Stop	Shutter speed	Flash Used	
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
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			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N
			☐	☐	☐					☐ Y	☐ N

Appendix 7

Total Stations are electronic surveying instruments comprised of an electronic theodolite, electronic distance measurer, and handheld computer. They are used to determine angles and distances relative to an established datum to accurately record precise three-dimensional spatial locations of any items of interest.

A. A total station must be set up over a datum. To establish an effective datum, select an area with high visibility. This area should have a clear view of as many items of interest as possible. After a proper datum has been established, the total station must be erected and leveled. If a total station is placed on an unleveled base, measurement errors will occur. It is recommended to mark and photograph the datum location and surroundings when the instrument is removed.

B. After the total station is set up and leveled, instrument height must be recorded. This will be the height from the center of the datum on the ground to the plus sign on the side of the total station. This must be entered into the measurement recording software. Next, a backsight must be established. A backsight is a means to calibrate the total station by measuring out a set distance north of the machine and entering the measure you set as the distance to the backsight with the measure generated by the total station. A backsight should be set up further than the furthest point of interest. This is done to reduce possible angular measurement errors.

C. After the backsight is established, the survey of the site can begin. The prism operator must go to each flagged evidentiary item and level the prism over the area of interest. Features should be labeled in a clear and concise manner. Each item requires an unique number. In addition to any evidentiary items of interest, permanent structures such as telephone poles, older homes, traffic signs, etc., should also be recorded. This will help serve as other points of reference and comparison.

D. The size of the object will determine the number of points to collect. The importance of size should be decided upon prior to collection. Larger items should be represented by multiple points. For example, if you are documenting a house, at minimum, each corner should be taken, or each point at which the angle of the house changes. Similarly, for Significant Evidence that is larger, the number of points should be sufficient to define that shape, i.e., wherever there is a deviation in shape outline, record a point. For intact or partially intact human remains, an outline of the body should be taken at major joints. This will allow for the orientation of the individuals to be retained post-collection (Appendix 4).

CHAPTER III

RESEARCH COMPONENT 2: EFFICIENCY TESTING

Materials and Methods

Introduction

Once the technological protocols were developed (*Research Component 1*), the next step was to test whether these protocols could be implemented in a reasonable amount of time, with a reasonable number of responders. *Research Component 2* was aimed at testing and further improving the protocols developed in *Component 1,* in terms of their efficiency. Efficiency was primarily measured in terms of time required to complete all of the steps of the protocols, under realistic conditions, compared to the unit of area searched and personnel used. This research component also provided feedback to *Research Component 1*, to further correct undetected technological configuration problems or issues.

Research Component 2 served to further validate the alternative technological configurations, and in particular, their applicability to real situations, in terms of time and personnel costs. Configuration comparisons also served to assess the differences in performance between them, providing a baseline for cost and needs assessments. The relationship between recovery times and number of items recovered serve to improve scene management. This improvement can be accomplished by providing estimates of the time required for scene processing (in real time) that depends upon the spatial density of evidence observed at the scene. This parameter of time-per-item recovered will also serve to correct for scene difficulty during inter-scene (or inter-protocol) comparisons, as higher densities of evidence will require longer processing times.

Feedback from independent observers taking part in the exercises provided necessary information for configuration and protocol validation and improvement. At the same time, it also served for protocol dissemination and further development by independent parties. Finally, post-processing of the bomb scenes created for *Research Component 2* afforded essential data for *Research Component 3*, aimed at assessing evidence density and recovery rates when the initial number of evidentiary items at the scene was unknown.

Work for *Research Component 2* consisted of the recovery and processing of a real plane crash in Clarence Center, NY, three mock bomb blast scenes, and three additional exercises in which technological configurations were tested and refined.

Original Research Design for Mock Scenes

Data for this research component were collected from realistic mock scenes, in which a vehicle containing an animal model was detonated. The research design was based on a series of field exercises carried out at Mercyhurst College and in Susquehanna County, PA, since 2004, as well as on the basic design of the Missouri (*Weldon Spring Protocols*) exercise described in the original project proposal (Dirkmaat *et al.* 2001, Reinecke and Hochrein 2008). These exercises were not much different from the common bomb drills routinely performed by many responder and law enforcement agencies. In these exercises, a vehicle was detonated, and the scene processed using the *Weldon Spring Protocols* described in the original project proposal.

Fully fleshed pigs (*Sus scrofa*), served as a proxy to human victims. After testing different alternatives, pig carcasses proved an appropriate and convenient model to approximate the response of explosions on human bodies. In each exercise, 2 to 4 pigs were fully dressed to further approximate the conditions of human victims, and placed inside the vehicle, in locations replicating those typically occupied by humans in a vehicle (Figure III-1). Each vehicle window was painted in different colors, using spray paint (Figure III-2). This allowed for the assignment of each glass fragment noted in the debris field to a particular location on the vehicle. In a number of the pilot exercises it was noted that, due to their high density and reduced surface area (less wind resistance), small glass fragments travel furthest away from the explosion site and follow consistent trajectories. These fragments thus provide a better spatial imprint of the vector forces associated with the explosion(s).

Figure III-1. An example of a fully clothed pig seat belted into the passenger seat of the vehicle.

Figure III-2. Each window was spray painted in a different color to enable assessing the origin of glass fragments after the detonation.

Prior to detonation, each scene was carefully mapped and documented. Two pounds of *Kinepak* were then placed at different locations in the vehicle, under the vehicle, or on the animal model (as bomb vests), and detonated. The amount of explosives was varied depending on vehicle characteristics. *Kinepak* is a detonator sensitive explosive composed of AN and Nitro-Methane. Mixed, it is classified as a 1.1D high explosive with detonating velocity ranging from 14,100 fps to 21,500 fps.

After the vehicle bomb was detonated, a crew of explosive specialists (members of the bomb squad) performed an initial examination of the area, in order to detect any remaining potential threats (e.g., undetonated explosives) and secure the area prior to the arrival of the recovery team. Once the scene was cleared, the principal investigator and his team made an initial assessment of the scene and organized the search crews, following the standard protocol for real scene situations.

The search, documentation and recovery crews consisted of law enforcement, first responders, coroners, and advanced forensic students who received a one-day training session on the protocols the day before each incident. The number of participants per exercise was between 20-30 individuals. In order to avoid pseudoreplication (Hurlbert 1984), the participants were randomly distributed into search teams for each search area and session (i.e., each participant took part in different successive search and recovery teams). Randomizing the search crews, and using different crews each time, allowed for a simplified statistical analysis, as it made the different search and recovery efforts independent from one another. In this way, the average differences observed in protocol outputs cannot be attributed to team biases (e.g., a particular team being more or less efficient, having a different background or, especially, having increased team organization and cohesion as they took part in successive searches).

The scene area was divided in approximately 10 x 30 m corridors, and a recovery team, following the *Weldon Spring Protocols* processed each of these corridors. The search crews of each team were composed of 5-10 individuals, separated approximately 2 meters from each other in a line search. Corridor assignment was also randomized, and different searches were carried out concurrently. Exact corridor area, time for completion of each of the protocol steps, and number of items recovered, both total and per time unit, were recorded.

Three of these exercises were carried out during the project period. Each exercise was carried out over a 4 day time period. The first day involved the teaching of the *Weldon Spring Protocols* to the participants and preparation of the scene and the bombing scenario (details unknown to the participants). The second and third days were devoted to scene processing by the independent crews, while during the fourth day the scene was post-processed by a crew of Mercyhurst AFS graduate students and faculty, in order to collect additional data for this component.

Plane Crash in Clarence Center, NY

At approximately 10:00 pm on February 12, 2009, Continental (Colgan) Flight 3407 crashed into a house in Clarence Center, NY en route to the Buffalo Niagara International Airport from Newark Liberty International Airport in Newark, NJ (Figure III-3). There were 49 passengers on board and one individual on the ground reported dead. The principal investigator was asked by the Erie County, New York, Medical Examiner’s Office (ECME: Buffalo, NY) to lead the victim recovery effort at the scene. Dr. Dirkmaat and several members of the Applied Forensic Sciences Department at Mercyhurst College arrived in Buffalo just hours after the crash. Recovery efforts at the scene were conducted from February 13-16, 2009.

This was the first opportunity for investigators at Mercyhurst College to employ their recently established recovery protocols (*Weldon Spring Protocols*). This unfortunate event afforded the investigators the opportunity to refine pre-disaster planning, recovery efforts, and collaboration with several other major groups (FBI; NTSB; local Medical Examiner’s office; fire fighters; etc.).

This incident provided necessary feedback in the pre-planning efforts for disaster scene management and collaboration with crucial groups in the holistic recovery and identification efforts at a mass fatality scene.

As stated above, recovery efforts were conducted at the scene from February 13-16 in which 49 of the 50 victims were recovered and the scene was cleared of all debris, including personal effects, plane parts, and house debris. The last individual could not be detected due to an intense burning of one particular area, which essentially cremated this individual. The PI and one other team member remained in Buffalo to assist the ECME and the Region II Disaster Mortuary Operational Response Team (DMORT) with victim identification at the Medical Examiner's office.

Figure III-3. The contained area found at the Continental Connection Flight 3407 crash site

This scene represented a more contained crash area, as compared, for example, with the much more dispersed crash scenes of USAir Flight 427 (Pittsburgh, 1994), or United Flight 93 (Somerset, PA, 9/11/2001), upon which the *Weldon Spring Protocols* were constructed.

In spite of the high degree of heat alteration and vehicle destruction observed at the Clarence Center plane crash, many of the victims (n=49) were more or less intact (most were still strapped into their seatbelts). This provided an excellent opportunity to refine the scene processing protocols to encompass a very different scenario as compared to widely dispersed crash sites describe in the *Weldon Spring Protocols*. A simplified but comprehensive alternative to the *Weldon Spring Protocols* was developed which can be applied in this type of confined crash scene (See *Research Component 1* in the Results section of this report).

Changes in Research Design based on Clarence Center Crash

One the main scene documentation issues observed during the Clarence Center recovery was a lack of guidelines for total station procedures (which were not conducted by Mercyhurst DAFS personnel at this scene). Even when total stationing was carried out by police officers that were very familiar, highly experienced and skilled in mapping other forensic scenes, problems remained. The lack of guidelines regarding which anatomical areas of the victims should be collected via the total station and total number of points to be taken when nearly intact bodies are present (as opposed to the small and fragmented remains most often noted via a single total station point, characteristic of other mass fatalities), resulted in delayed efforts, and substandard spatial evidence recording at the scene. Therefore, a set of standard, quick, and user-friendly total station guidelines were subsequently developed for these situations.

Post Bomb Blast Recovery Exercises

Efficiency testing was carried out during three post bomb blast recovery exercises that were conducted during the project period. The first exercise was carried out in the summer of 2009 in Wattsburg, PA. This exercise was carried out during a post bomb blast recovery course. The second exercise was complete in the fall of 2009 in Williamsport, PA and the third was carried out during the summer of 2010 in Erie, PA.

1. June 22-26, 2009: Wattsburg, PA

One of the major goals of this mock bomb scene was to test the efficiency of the new technological configuration created in *Research Component 1* based on time and personnel costs. Apart from the complete processing of the scene, which allowed estimating overall scene parameters, two 10 x 30m corridors were created on each immediate side of the detonated vehicle to test the newly modified recovery protocols.

Prior to detonation, the scene was carefully mapped and documented. Two pounds of *Kinepak* was then placed within the vehicle. As stated above, *Kinepak* is a detonator sensitive explosive composed of AN and Nitro-Methane. Mixed, it is classified as a 1.1D high explosive with detonating velocity ranging from 14,100 fps to 21,500 fps (Figure III-4).

A total station was used as the master, primary datum, with a second one being referenced based on the coordinates recorded by the master for the datum of the second total station. This is to say the datum and back site of the second total station were recorded with the first one. The coordinates obtained where then entered in the second total station as its datum and back site coordinates. In this way, both total stations would be operating in the same coordinate system, so that their data could be directly merged with minimal post-processing of the data.

Figure III-4. An example of Kinepak recovered at the scene of one of the mock bomb exercises.

Protocol Modifications

Corridor A was processed using the new technological configurations in their current state of development, using handheld computers and a barcode system, while the second corridor (Corridor B) was processed using total station and manual notation (Figure III-5). Times for completing each individual step of the recovery were monitored in these corridors. The average time for completion of each component of the recovery effort (total station data collection, photographic data collection, and actual collection time of each item) was compared between the two corridors. This allowed us to assess which of these components required the longest time to complete, thus providing the limiting element of the recovery protocol. Given that the proposed protocols allow for simultaneous and independent work of the different teams, the time it takes to complete each task is particularly important. Due to this limiting factor, more teams should be assigned to the slower, more time limiting tasks (for example, if evidence collection takes almost double the time that photographic documentation takes, two collection teams for each photographic team is recommended). See *Research Component 2* in the Results section of this report for information on this topic.

Figure III-5. Photograph of the Wattsburgh, PA bomb blast and subsequent line searches, photography team and total station team.

2. September 19, 2009: Williamsport, PA

The second bomb scene exercise was carried out on September 19, 2009, in an old landfill in Williamsport, PA (Figure III-6). A 160-pound pig was placed in a vehicle that was subsequently detonated. The recovery team consisted of 32 individuals.

All search corridors were processed using the bar-coding protocol successfully tested in the previous exercise of this type (Wattsburg, PA) adding the enhancements in database notation. One of the major goals of this mock scene was refining and testing the efficiency of the field protocols for total station data integration when multiple total stations are employed simultaneously, a realistic scenario when processing large scenes. Additionally, an R8 GNSS (Global Navigation Satellite Systems) receiver, lent for the exercise by an instrument retailer, was also tested with a tetherable cell phone (military grade) configuration. In this manner, two total station teams, plus an R8 team collected data simultaneously.

Figure III-6. Bomb blast site in an old landfill in Williamsport, PA.

Additionally, the amount of explosive was reduced and placed in a manner to result in a more constrained evidence dispersion pattern, more similar to the contained scenes addressed by the new *Clarence Center* variant of the protocols, proposed after the *Colgan* Flight 3407 recovery, at Buffalo, NY (See *Research Component 1* in the Results section of this report). The bomb materials used for this vehicle were: a 4.5 pound texpak pipe bomb, 30 feet of 50 grain DEP cord, and a 1 pound cast booster.

The search teams were composed of volunteers from different local and state law enforcement and first response agencies, who had taken part in an emergency response short course the previous week. These volunteers had been instructed in the proposed protocols during the short course, and offered the possibility of participating in the research exercise. Feedback on the protocols, the instructional materials, and the availability of the required equipment at their respective agencies was compiled and examined for protocol and training enhancement.

As stated above, in the previous exercise (Wattsburg, PA), a total station was used as the master, primary datum, with a second one being referenced based on the coordinates recorded by the master for the datum of the second total station. While efficient, this system poses some practical limitations. First, both total stations must be placed within sight of each other. Secondly, discrepancies in the distances from the datum to the back site recorded by both devices can be problematic. It is difficult to define which of the instruments is generating the error, and detected measurement errors will likely result in the necessity of resetting one or both total stations more often than when a single instrument is employed, conversely resulting in longer setting times and delays. Thirdly, the same problem will likely arise every time that the secondary total station is moved to a new datum.

The proposed improvement to circumvent this problem, tested in this exercise, was entering the GPS points of both data and back sites, as the original grid reference coordinates, in both total stations used. In this way, total station data integration was attained directly when integrating the total station and GPS data, rather than as a step preceding the later. This does, however, require the total station operators to set-up the equipment over an established datum, which can be time consuming.

When the conventional GPS (*Trimble GeoX*) was used, this resulted in some delay in setting both total stations. This is due to the time necessary to obtain GPS coordinates with sub-meter accuracy. This is achieved by taking a large number of data readings while the GPS receiver is kept stationary at the point of interest (e.g. the total station datum). This results in a more or less circular cloud of points, each of these points representing a different reading of the same point location, with the added random error. The point coordinates are then obtained from the centroid (geometric center) of this cloud of points, and the error rate of this estimate will be the standard error of the distances of all points to the centroid. This standard error is inversely proportional to the number of readings (points in the cloud) that are taken. This is to say, the more readings taken, the smaller the measurement error becomes.

The number of readings that need to be taken at each point in order to attain the appropriately small error rate will depend on different factors, especially the number of satellites used to obtain the reading, and their relative location (i.e. satellite geometry, measured by the *Perceived Dilution of Precision*, PDOP). Therefore this number will vary from point to point, being almost impossible to estimate it accurately in the field. Thus, in practice the only way of ensuring a good precision in all cases is always recording a set number of readings, large enough to provide optimal precision even in the worst-case scenario.

Typically, it is considered that 600 readings (also known as moments; a moment is one communication, or reading, from the satellite to the receiver) will always ensure the smallest possible error under the worst conditions (even if being over kill in most cases). It is not casual that this figure coincides with taking one reading per second along ten minutes. Therefore, recording the GPS data for the total station datum requires a delay of at least ten minutes in setting the first total station, 20 minutes for the second, etc. In spite of these delays, this procedure reduces significantly the time required to integrate the data from different total stations, well beyond the time employed to implement it at the field. Additionally, as explained above, direct referencing of a second total station from a master one is also time consuming and problematic.

However, when sub-meter resolutions (error rates) from conventional GPS data are employed, post-processing work for data integration is still far from easy or unnecessary. Basically, it requires overlaying and rotating our data plots to minimize the distances of the GPS and total station readings for a subset of points, and this fit will not always be necessarily good (See in *Results* section below).

Figure III- 7. Team member using the R8 Survey Grade GNSS receiver to map corridors.

A single team member mapped a complete corridor in less than two hours, using the R8 for the first time (Figure III-7 above). This time reduction also allowed the setting of two total stations almost immediately, so that all data taken during the exercise were immediately georeferenced with great accuracy. As a matter of fact, it was observed that the error rates obtained with the R8 are less than even those derived from the total station prism or the GPS pole. Therefore, the R8 is capable of substituting the total station without any practical accuracy or precision loss. Finally, the instrument was tested with the original cell phone provided by the retailer, as well as with an iPhone operated by a different phone company. The R8 software was able to detect the new cell phone immediately and to reconnect to the base through the provided phone number (basically, the phone connects to the device via *Bluetooth* and sends text messages to the base center to receive corrections. It is then necessary for any potential phone to include *Bluetooth* and text messaging capabilities).

3. June 23-25, 2010: Erie, PA

The third bomb exercise was carried out during the 7th Annual Post-Bomb Blast Recovery Short Course hosted by Mercyhurst College. This exercise took place June 23-25 of 2010 in Erie, PA.

This exercise focused on the final testing of the wireless communication elements. During this exercise, an automobile was detonated following the protocols described above. The detonation resulted in a fairly contained distribution of the evidence, covering approximately four search corridors. Line searches were carried out in all of these corridors, while the two more densely populated of them (i.e. those immediately surrounding the detonation area) were documented and processed following the complete protocols.

A total station unit was used to demonstrate its use within protocols to the course attendants, as well as to generate a topographic map of the general scene. The exact location of all evidentiary items was instead recorded with the R8 GNSS unit (now being tethered through Wifi via a mobile hotspot), and its tagging and documentation was carried out through the bar-coding system. Additional repeated line and plotless searches were carried out for *Research Component 3* during this exercise.

As the recovery times (efficiency) had already been well established in the previous exercises, the exercise was also employed to assess its ease of application by third parties after minimal training. With this objective, the course participants were allowed to implement the protocols in one of the corridors, rotating through the search, provenience, photography and collection teams (Figure III-8 and III-9).

Figure III-8. Line searches following the detonation of the bomb for the Post-Bomb Blast Recovery Short Course.

Figure III-9. Post-bomb blast with corridors in place and searches started. Note the number of flag evidentiary items, especially concentrated around the vehicle.

The bomb blast exercise in Erie, PA revealed a very steep learning curve for the protocols, with all participants being able to familiarize themselves, operate the equipment, and correctly apply all the steps of the protocols after just a couple of hours of training and practice, particularly when the R8 GNSS substituted the total station. This was also confirmed by the feedback received from all participants.

Other Exercises Used for Testing Equipment and Technology Configurations

Three additional exercises were used to test equipment and technological configurations. A number of mock fatal fire scenes were processed during field exercises for another NIJ funded grant awarded to the principal investigator and two other Mercyhurst College professors (*Award No. 2008-DN-BX-K131*). Investigators used these scenes to test and refine technology and technological configurations produced for this project. This allowed for a reduction in the amount of funds necessary to carry out equipment testing and refinement of configurations.

The first exercise was conducted September 25-27, 2009 in Malahyde, Ontario. Various equipment items were tested during this mock fatal fire scene. Components of the *Weldon Spring Protocols* were employed for search and collection teams. The second mock fatal fire scene was processed November 5-8, 2009 in Franklin Center, PA. During this exercise the R8 GNSS unit was tested and used to create a georeferenced map of the trailer fire and associated evidence. The third exercise in which technology was tested was conducted November 20-22, 2009 in McDonald, PA. During these exercises barcode configurations, documentation configurations, and data integration was tested and refined for this project.

Results

Comparisons of each technology configuration have also served to assess the differences in performance between them, providing a baseline for cost and needs assessments. The relationship between recovery times and number of items recovered serve to improve scene management by better estimating the number of personnel required for a specific incidence. This improvement can be accomplished by providing straightforward estimates of the time required for scene processing (in real time) that depend on the spatial density of evidence observed at the scene. The parameter of time-per-item recovered can also serve to correct for scene difficulty during inter-scene (or inter-protocol) comparisons, as higher densities of evidence will require longer processing times.

Wattsburg, PA Bomb Blast Recovery Exercise: June 22-26, 2009

Contrary to common belief, total stationing, including item description and unique number assignment, is the fastest of all the recovery tasks. This was already evident during the recovery exercise of the mock bomb blast site, with collection and photography teams lagging behind the total station team. In Corridor A (recovery protocol included barcoding), 374 evidentiary items were mapped and catalogued in around 3 hours and 15 minutes of total station time, with an average time between 28 and 33 seconds (95% interval) per total station point, and a median of 28 seconds per point. A total of 95% percent of the recovered elements required less than 55 seconds of total station time, and the element requiring the longest time to be recorded by the total station and handheld database only required slightly more than 4 minutes, though this was due to angle measurement errors on the theodolite that required recalibration before the point could be recorded.

These results stand in stark contrast with the general assumption that recording more than one point (at the "center of mass") on each body is not feasible at a plane crash because of time constraints. This was the reasoning behind the small number of total station points taken during the Clarence Center, NY plane crash recovery. The recordation of each total station point took a long time, likely due to the difficulty in assessing the location of the center body mass of a victim, holding the prism above this point, while avoiding altering the body, and the lack of standardized guidelines on the sequencing and referencing of total station efforts and data. Figure III-10 shows the projected total station times to process 1 to 100 victims, based on results in this research project. Depending on the degree of detail used to describe body positioning and location (i.e., taking either 5 or 13 points per victim). The obtained times, around 30 seconds per total station point, also provide a preliminary guideline to assess the desirable objectives to be attained during training for response to this type of scenario.

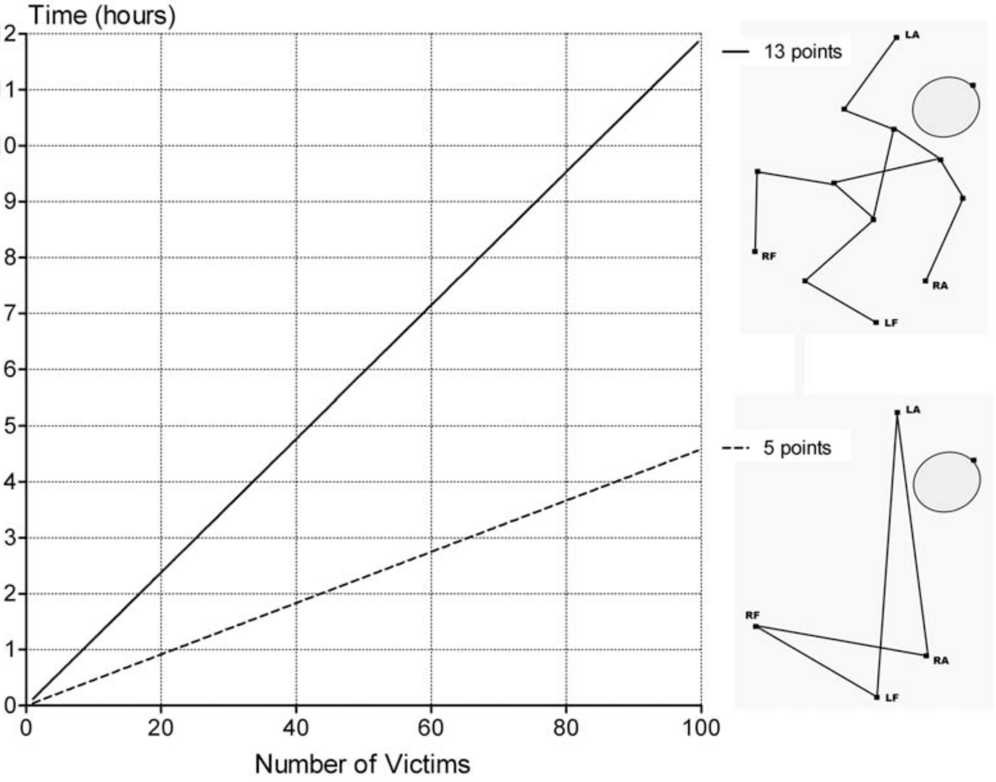


Figure III-10. Projection of total station times required to process different numbers of victims, based on the most conservative estimate for average time per total station point (33 seconds; upper 95% limit for the mean) obtained in this bomb exercise. Note that taking 13 total station points per victim in 100 victims would take less than 12 hours of total stationing time.

Furthermore, the average time to collect each point for the total station seem to remain constant, at least over periods of around three hours of continuous recordation by the same team. Figure III-11 shows the distribution of times per point along the sequence of points recorded. A gradual increase in time is observed at the end of the sequence, but a segmented regression analysis revealed that this increase tendency coincided with the breakage of one of the total station fine-tuning knobs (the inflexion point in the plot line; $x_0=337 \pm 34$), which resulted in a more difficult operation of the device. This problem prevented reliable observations of the performance for a longer period of continuous work. However, before this point in time, the slope of the line was not significantly different from zero, which was confirmed by a lack of Spearman correlation between time per point and rank order of point taken (r= -0.05787, non significant at the 0.05 level, Gaussian approximation.) This strongly suggests that fast and effective total station recordation by a single team can be sustained for several hours.

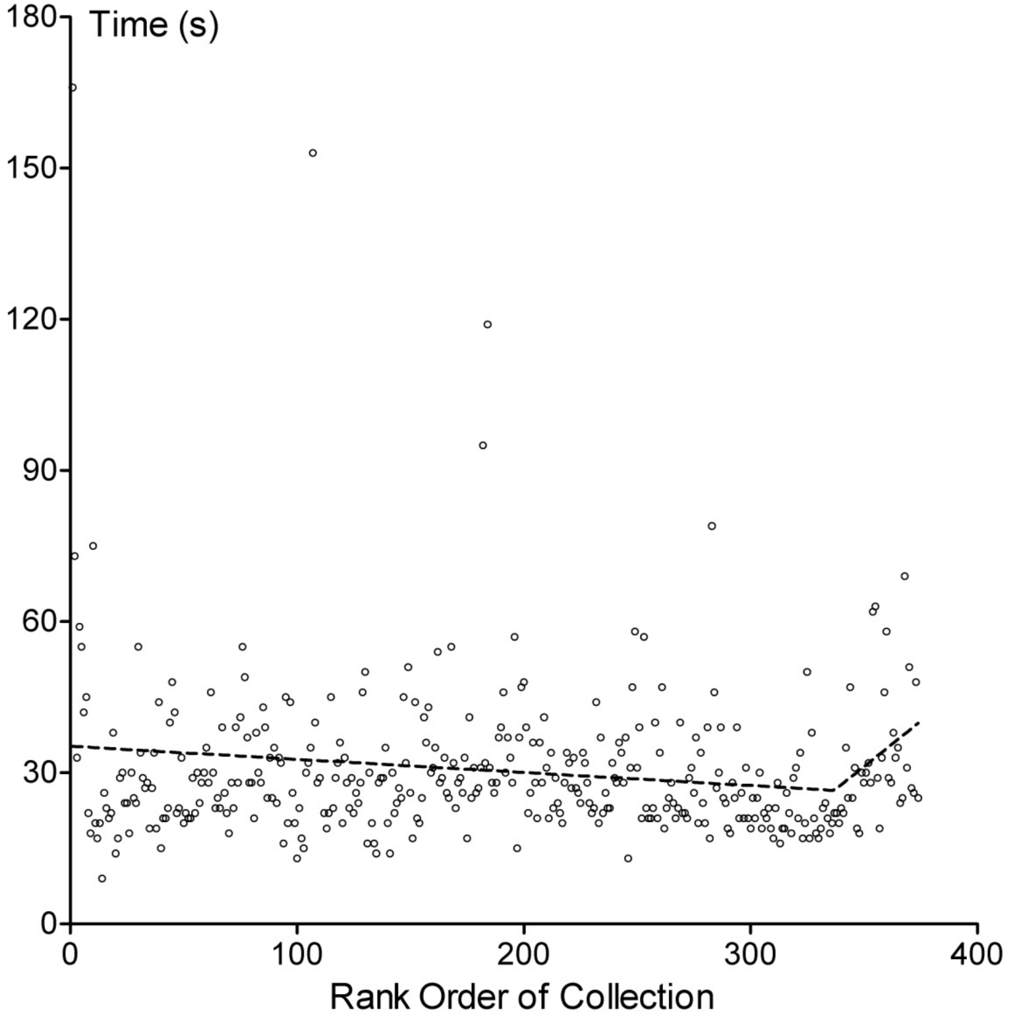


Figure III- 11. Evolution of total station times per unit as the collection progresses. The dotted line represents the segmented regression line. The change in tendency observed at the end of the sequence is explained by the breaking of a fine-tuning knob in the total station (see text for explanation). The slope of the line before this point is not significantly different from zero, suggesting that total stationing efforts can be efficiently sustained for several hours by the same team.

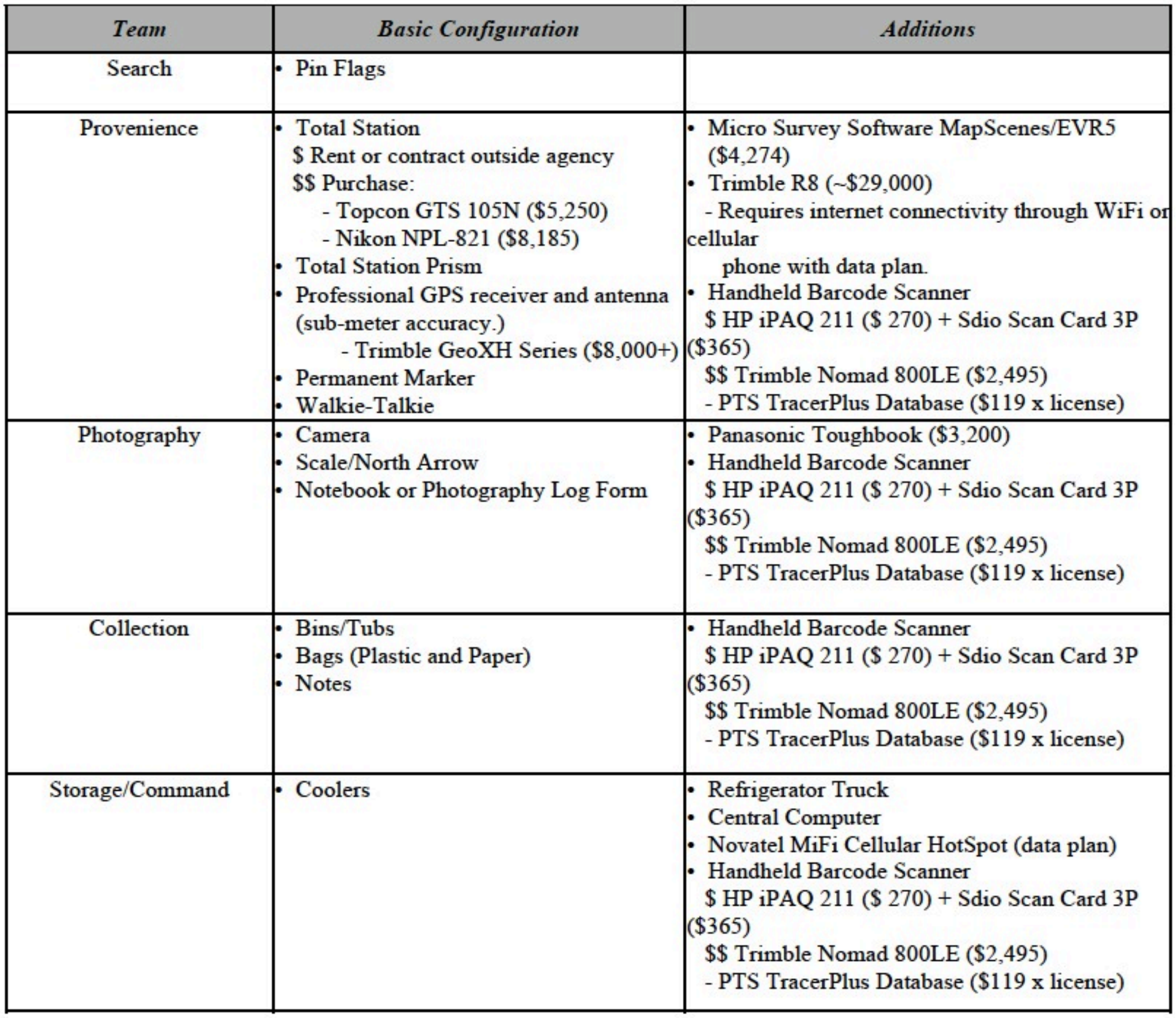
In order to test and refine the protocols for data combination and sharing between two different total stations and software platforms, two total stations with different software configurations (*Trimble* and *Evidence Recorder*) were employed in the exercise. Each software configuration allows the user to export the spatial data into different file formats. CSV (comma separated values) and SHP (shapefiles) are preferable when combining datasets. Both of these formats can be integrated into a GIS (geographic information system) and combined. Preferably, each total station used should be over an established datum with known GPS coordinates. In this way, no post processing will be necessary to link the data. If the total stations are not geo-referenced, at least 4 points in common must be taken in order to later link the data.

Finally, two plotless searches, as described in the project proposal, were performed in the two test corridors after the initial search, followed by successive line searches (*plot methods* in the original proposal), intended to estimate the amount of evidence missed during the initial searches. These data suggest that initial recovery rates were very high in these close-to-real exercises.

Advances in this component have already been briefly described in the preceding sections. In addition to the final field test exercise, the technological elements and configurations of the protocols have been also repeatedly tested in different forensic case scenes, under different terrains and environmental conditions, as well as on the exercises related to another ongoing NIJ research project (*Recovery and Interpretation of Burned Human Remains*, Award No. 2008-DN-BX-K131), with all glitches and technological problems seemingly solved. Table III-1 below briefly summarizes the current technological component options of the low-end and high-end technological configurations.

The recovery times (efficacy) obtained for the protocols in all these situations are basically identical than those obtained in previously reported exercises, with average times of around 30 seconds per point in the recording phase, and the photographic documentation as the slowest phase, which is corrected when bar-coding and two photography teams per provenience (total station or R8) team are employed.

Table III-1. Technological configuration options and additions.



Team	*Basic Configuration*	*Additions*
Search	• Pin Flags	
Provenience	• Total Station $ Rent or contract outside agency $$ Purchase: - Topcon GTS 105N ($5,250) - Nikon NPL-821 ($8,185) • Total Station Prism • Professional GPS receiver and antenna (sub-meter accuracy.) - Trimble GeoXH Series ($8,000+) • Permanent Marker • Walkie-Talkie	• Micro Survey Software MapScenes/EVR5 ($4,274) • Trimble R8 (~$29,000) - Requires internet connectivity through WiFi or cellular phone with data plan. • Handheld Barcode Scanner $ HP iPAQ 211 ($ 270) + Sdio Scan Card 3P ($365) $$ Trimble Nomad 800LE ($2,495) - PTS TracerPlus Database ($119 x license)
Photography	• Camera • Scale/North Arrow • Notebook or Photography Log Form	• Panasonic Toughbook ($3,200) • Handheld Barcode Scanner $ HP iPAQ 211 ($ 270) + Sdio Scan Card 3P ($365) $$ Trimble Nomad 800LE ($2,495) - PTS TracerPlus Database ($119 x license)
Collection	• Bins/Tubs • Bags (Plastic and Paper) • Notes	• Handheld Barcode Scanner $ HP iPAQ 211 ($ 270) + Sdio Scan Card 3P ($365) $$ Trimble Nomad 800LE ($2,495) - PTS TracerPlus Database ($119 x license)
Storage/Command	• Coolers	• Refrigerator Truck • Central Computer • Novatel MiFi Cellular HotSpot (data plan) • Handheld Barcode Scanner $ HP iPAQ 211 ($ 270) + Sdio Scan Card 3P ($365) $$ Trimble Nomad 800LE ($2,495) - PTS TracerPlus Database ($119 x license)

Williamsport, PA Bomb Blast Recovery Exercise: September 19, 2009

A single team member mapped a complete corridor in less than two hours using the R8 for the first time. The resulting map is depicted in Figure III-12, and was obtained the same day. This time, the other two total stations were erected over data geo-referenced with the R8, so that all data taken during the exercise were immediately geo-referenced with great accuracy. As a matter of fact, it was observed that the error rates obtained with the R8 are inferior to those derived from the placement of the tip of either the total station prism, or the GPS pole. Therefore, the R8 is capable of substituting the total station without any practical accuracy or precision losses.

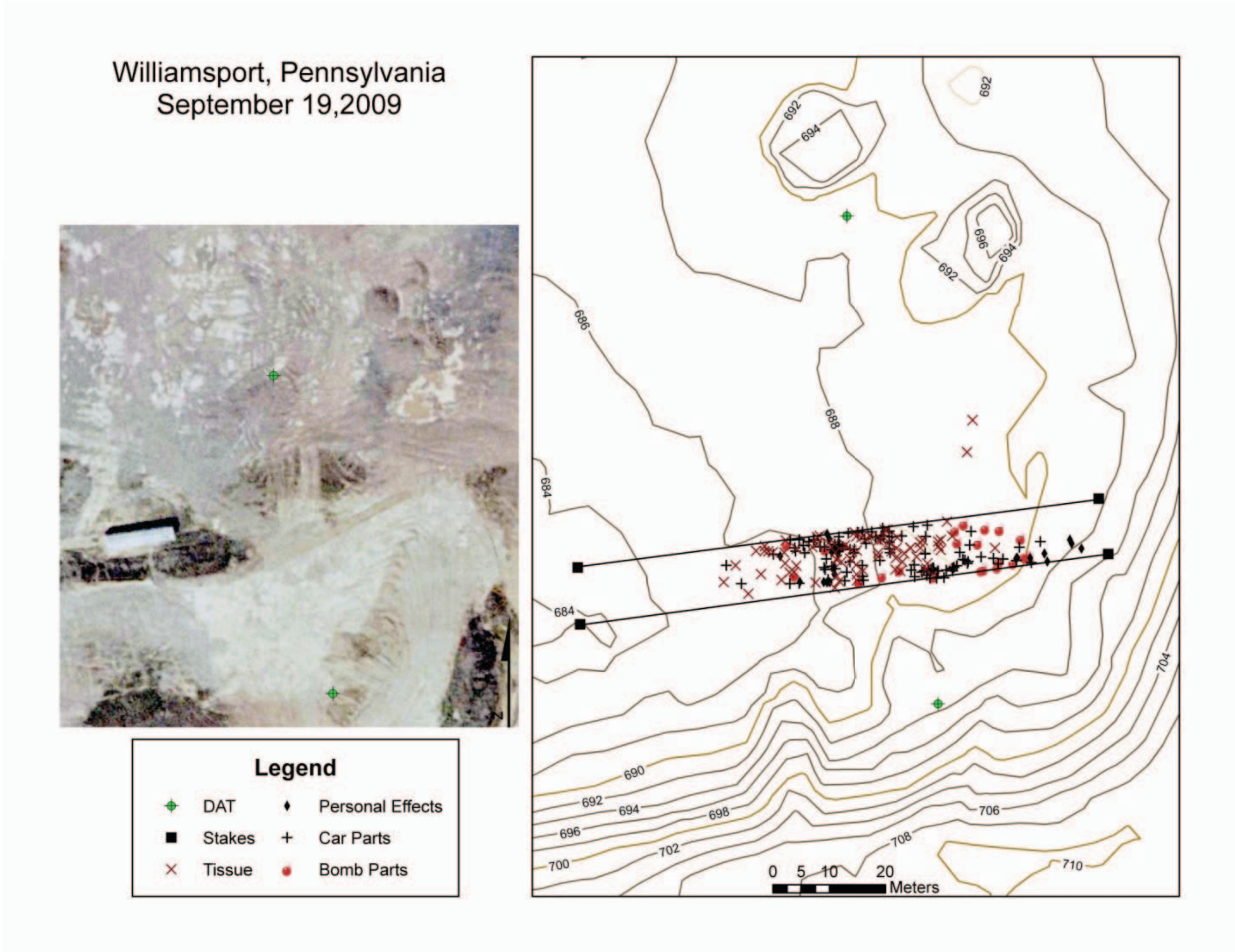


Figure III-12. Aerial photograph and topographic map depicting the data collected at Williamsport with the R8 GPS unit. This map was produced just a few hours after the exercise. This was the first contact of both the data collector and the map producer with this device. The reduction in both data recordation and post-processing times is dramatic when compared with the total station, with minimum training required and precision losses.

The plot (capture-recapture) sampling exercises reveal a very high efficiency of the search protocols under the current experimental conditions, with recovery rates above 90% per single search in all cases, and often with 100% recovery rates. While these figures allow for a very optimistic protocol efficacy assessment when the realistic, mock bomb scenarios are considered, they may also suggest that evidence detection potential may be overestimated in the experimental conditions set for the Missouri-style exercises, resulting in potential biases toward density underestimation in the plotless, distance sampling equations. In other words, the mock evidentiary items may be too easy to spot under the current conditions, to realistically represent a situation in which the major evidentiary items have already been recovered, and sparser, harder to spot items remain at the scene, as was the aim of the proposed design.

The initial evidence density estimates obtained through plotless searches show central figures very close to the real values, apparently regardless of item sizes, as well as consistent decay lines with distance from the observer, at distances (*d*) within four meters, in spite of obtaining high detection rates (on average above 70%, and in many cases above 90%). See Figure III-13 as an example). This seems to suggest that, as predicted by the distance method, the ease or difficulty to detect the items do not play a role or is biasing the results. However, the current sample (number of replicas) is still too small, providing confidence envelops way too wide to extract any reliable conclusions, and it seems more advisable to refine the design in order to definitely assess whether these biases are present or not.

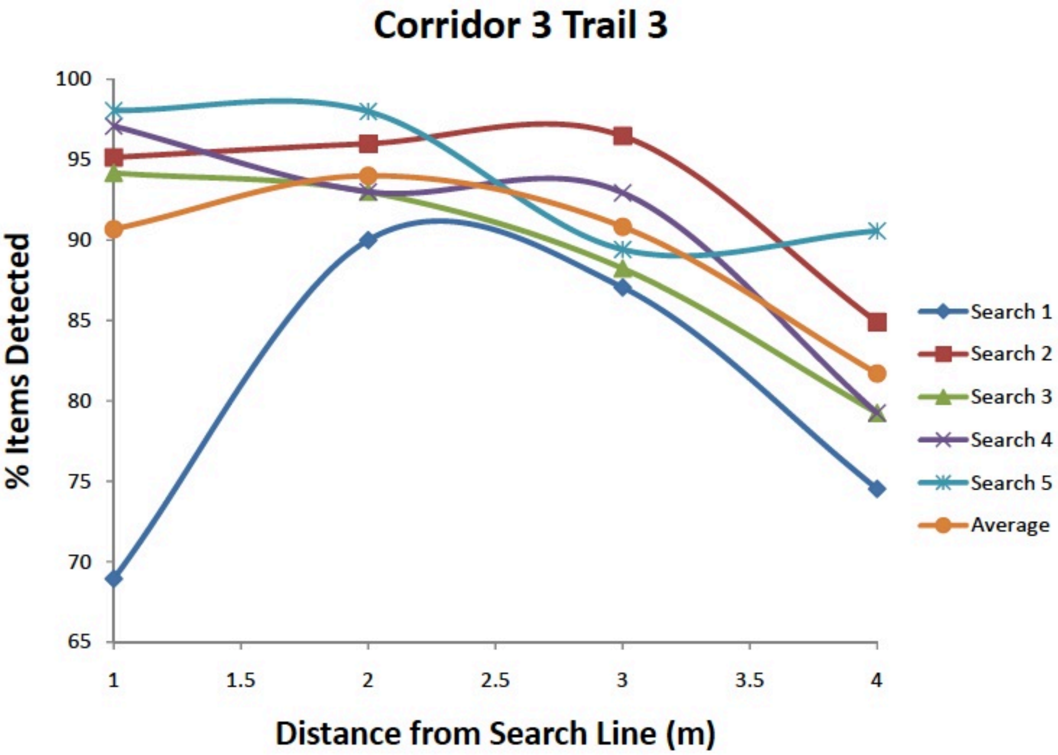


Figure III-13. Evolution of detection rates with distance from the observer in a plotless search (distance sampling) exercise. Note the high detection rates (above 90% for all but one participant).

Issues with Total Station, regular GPS and R8

When sub-meter resolutions (error rates) from conventional GPS data are employed, post-processing work for data integration is still far from easy. Basically, it requires overlaying and rotating the data plots acquired from the GPS or total station to minimize the distances of the readings from each to form a subset of points, and this fit will not always be necessarily good and may have different degrees of distortion in different planes.

This problem seems to be solved when an R8 GNSS system is employed, and the right conditions (good satellite reception) are present. During this exercise, the time required by the instrument to get a point reading with an error under 0.5 inches (and typically under 0.2 inches) was under 10 seconds, with a mode around three seconds. Compare this figure with the mean of 33 seconds reported for the Wattsburg, PA exercise, for the improved total station data collection protocols. The instrument also showed to be extremely user friendly. It was set and taking points within five minutes of taking it out of its case. This is particularly impressive taking into account that the particular R8 unit tested during this field exercise had been provided to the recovery team scarcely a few hours before the exercise, followed by around 20 minutes explanation of its usage. Although it must be noted that part of the team was already familiar with an earlier version of the software, provided with older GeoX GPS units, the instrument was also tested by graduate students not familiar with the former, being able to correctly operate the new instrument after very brief field explanations. Once the initial configuration parameters are set (these parameters can be fixed in advance as default settings), an individual can operate the instrument with almost no training. Similarly, anybody being familiar with GeoX GPS units can correctly enter all settings, with minimal changes from preceding versions of the software.

Erie, PA Bomb Blast Recovery Exercise: June 23-25, 2010

The bomb blast exercise in Erie, PA revealed a very steep learning curve for the protocols, with all participants being able to familiarize themselves, operate the equipment, and correctly apply all the steps of the protocols after just a couple of hours of training and practice, particularly when the R8 GNSS substituted the total station. This was also confirmed by the feedback received from all participants.

CHAPTER IV

RESEARCH COMPONENT 3: EFFECTIVENESS TESTING

Materials and Methods

Introduction

As previously discussed, one of the key goals of scene processing in a mass disaster is the “complete documentation and recovery of human remains and items of evidence” (Department of Homeland Security 2007, p. 8). Therefore, a key measure of the “success” of a mass scene processing protocol is the rate of recovery of physical evidence. That is, the proportion of evidence recovered relative to the total amount of evidence actually present at the scene. Recovery rates will depend primarily on the first step of the recovery protocols, namely search and location of evidence.

This dependence on recovery rates poses a key methodological problem when trying to address questions like the comparative performance of protocol modifications, the efficiency and effectiveness of our current recovery effort, what is the best strategy to deploy and manage our resources in a particular scene, or providing realistic estimates of the time and personnel that will be required to complete the recovery effort. At wit, the answers to all these questions ultimately depend on the amount and spatial distribution of the evidence present as the scene.

The problem is that in a real scenario we will not know this information beforehand, as we do in test and training exercises such as the Missouri-style field exercises described above (Dirkmaat *et al*. 2001, Reinecke and Hochrein 2008). How can we assess if we are being effective in recovering all evidence, tell authorities and media approximately how long it will take to process the scene, how many personnel will be required, or whether we can release a particular area if we do not know how much evidence was initially present, and how much of it may still remain at the scene?

Direct counts of the evidentiary items recovered per unit time can serve to compare protocol configurations and modifications, assuming that the areas processed with each alternative protocol share similar evidence densities (number of evidentiary items per unit area) and distribution, the later including both size and spatial distributions. By these measures, the recovery strategy and protocol configuration producing more items per unit time will be the more efficient one. However, the most efficient configuration may still not be effective enough in a real scenario. Recovering a large amount of evidence does not suffice if a comparatively large amount of human remains and evidentiary items still goes undetected at the scene. Therefore, reliable and realistic estimates of evidence densities at different areas will still be essential for optimal scene management.

Research Component 3 addressed these problems through: 1) the development and testing of reliable strategies and methods to estimate the amount of evidence present at the scene, and 2) the application of the developed search strategies and density estimates to the mock bomb blast scenes (described in *Research Component 2)*, to assess both their effectiveness and applicability in quasi-real conditions, and the recovery rates associated with each recovery protocol configuration.

These search and density estimation techniques are applicable to real situations, providing reliable, time- and personnel-economical means to assess the amount of evidence still present in a particular area, both before and after it has been already searched.

Research Design and Methods

Data for this research component were collected from two sources: 1) simplified Missouri-type scenes, with known evidence densities and homogeneous terrain characteristics, and 2) post-processing of the bomb drill scenes created in *Research Components 1* and *2*.

The research design for this component was based on exhaustively tested field ecology sampling methods, employed in the estimation of species abundances (Borchers *et al.* 2004, Buckland *et al.* 2001). These methods require the recordation of precise spatial coordinates of the evidence, or counts of evidentiary items per unit area, as well as the recordation and monitoring of the evidence recovered in successive searches. Traditionally, these data were not routinely recorded at mass disaster scenes, but the protocols developed in this study make them readily available, especially when efficient data transmission protocols are implemented, allowing for rapid onsite data analysis and parameter calculation.

For the first data source, simplified versions of the Missouri-style exercise were created at Mercyhurst College, on a smaller scale but with a much higher number of experimental replicas. In these exercises, different search strategies were applied to obtain density estimates in a number of experimental search regions of known surface area and item density.

The mock evidentiary items for these exercises consisted of series of porous concrete fragments of varying sizes, paint-coated to mimic colors of the grassy substrates. To produce these items, concrete blocks were manually broken up with hammers into 1800 pieces of different sizes. These fragments were then painted with hunter green *Krylon Stain* finish spray paint and black *Rust-Oleum Flat Protective Enamel* spray paint. After several tests, this combination of coatings resulted in an appearance akin to that of charred remains and materials found in vehicle crashes and bombing scenarios, as well as the less conspicuous in the grassy terrain in which the exercises were carried out. This made them not readily identifiable, as is the case with other elements commonly used in mock exercises, such as plastic bone replicas.

Each concrete evidentiary item had a small area (approximately 1 cm by 5 mm) coated twice with clear nail polish, in order to seal a space for numbering. The items were then numbered consecutively from 1 to 1800. The numbers were written on the painted concrete with white Bombay India ink and, after drying, were given a sealing coat of clear nail polish to avoid erasing during the exercises if the item came in contact with water.

After numbering, each item was weighed to the closest ±0.2 g, and all weights linked to the corresponding item number. As explained in the awarded proposal, given that all the items are solid blocks of the same material, their weight provides a good estimate of their size, which is expected to strongly correlate with detectability. Weights ranged from a few tenths of a gram to approximately half a kilogram (Figure IV-1). The weight distribution of the sample departs from normality (D'Agostino & Pearson omnibus normality test, $K_2 = 696.7$; $p<0.001$), with a long tail toward higher weights (skewness = 1.966). While not affecting the calculations for the plot and plotless (distance) density methods discussed below, this skewed distribution, with the median displaced toward small size ranges, was preferred in order to prime difficult detection conditions (a prevalence of small mimetic objects), to avoid over-estimation of recovery rates, while still considering a large size range of evidentiary elements, similar to that found at real scenes.

After number randomization, the evidentiary items were then stored in groups of 50 in randomly numbered paper bags and boxes, in order to obtain also a random size and appearance distribution in the corridors created for the exercises. Only 500 to 1500 of these elements were utilized per exercise, and the double randomization protocol was repeated after each exercise. Also to avoid pseudo-replication fragmented or lost items were substituted with new ones with new reference numbers. As a consequence, each one of the search exercises contained different mock evidentiary items, further distinguished by the different spatial distribution of the items during each exercise.

Three of these exercises were carried out at different locations on the campus of Mercyhurst College in Erie, PA, and Franklin Center, PA. A total of four rectangular 30x10m corridors were created in these exercises (1 + 2 + 1), according to the general methods described in the project proposal.

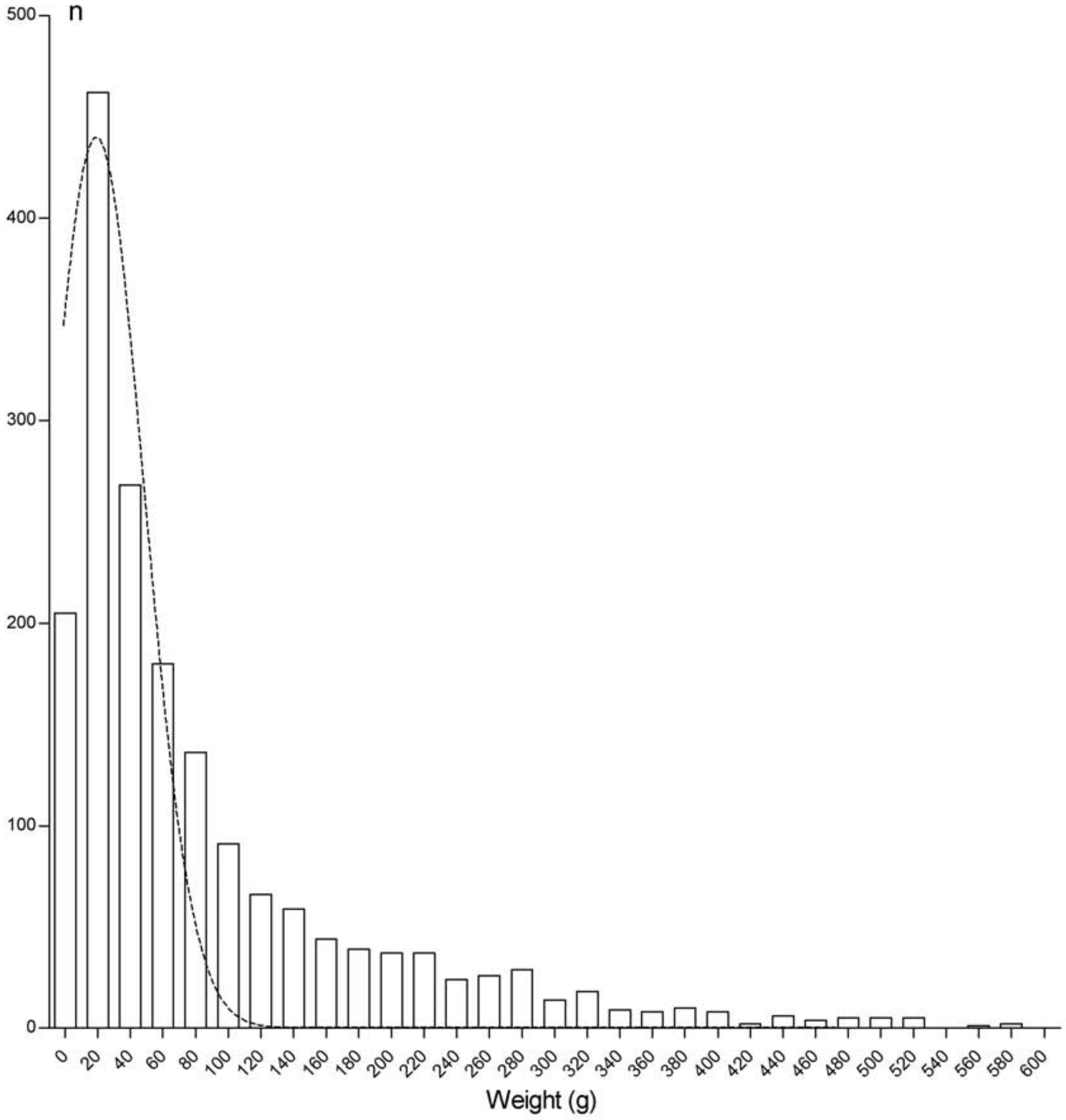


Figure IV-1. Mass distribution of the mock evidentiary items used in the Missouri-type exercises. Note the distribution skewed toward small sizes (100 g and smaller).

In the first two exercises (three search areas), 1500 mock items were quasi-randomly distributed across the search area. On the first day of the Search Protocol, five to ten assistants arbitrarily tossed a matching number of surveying flags along the search corridor. A mock evidentiary item was then placed at the tip point of each flag stem, following the randomized order described above. The exact location and reference number of the evidentiary items were then recorded using the Total Station. As the items were mapped, the flags were removed. The corridor stakes, lane points and distance search lines were also mapped to establish a reference framework for searches and items (Figure IV-2 and Figure IV-3).

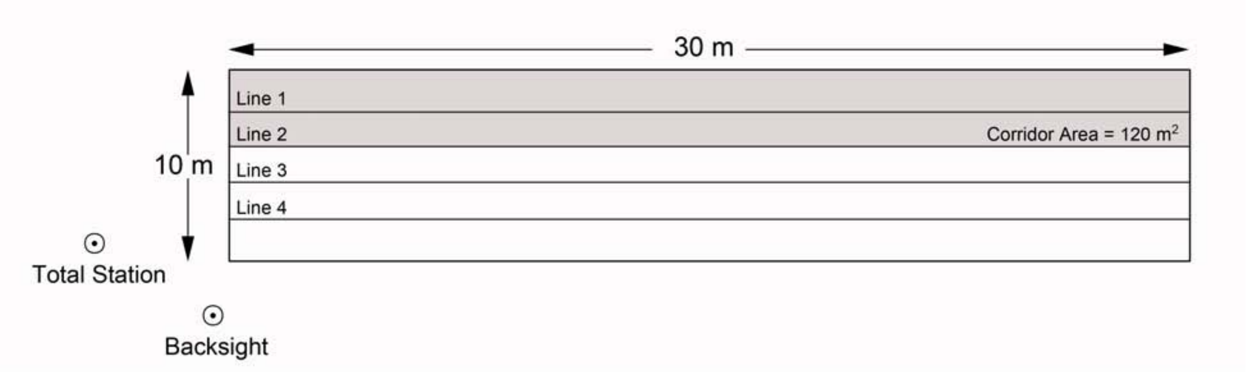


Figure IV-2. General arrangement and dimensions of each of the search areas in exercises 1 and 2. In these initial exercises the effective search area, beyond which the searcher was asked to ignore any detected objects, was set to 120 m2, defining a search distance of 2 m at each side of the search line. These boundaries were removed in search 3, increasing the effective search area to around 150 m2. A Trimble R8 GPS unit replaced the total station in exercise 3.

For the third search exercise, the number of objects was reduced to 800. These densities were selected based on the ones observed in the mock bomb blast exercises in *Research Component 2* above (under 400 items per corridor in all cases), in order to match more realistic scenarios. A Trimble R8 GPS was used instead of the Total Station to collect the data in this exercise.

Two different density estimation methods were then tested on these searches: *Plotless methods*, aimed at providing early density estimates before the areas are line-searched, and plot methods, based on the decreasing rates of materials detected as a particular area is line-searched multiple times.

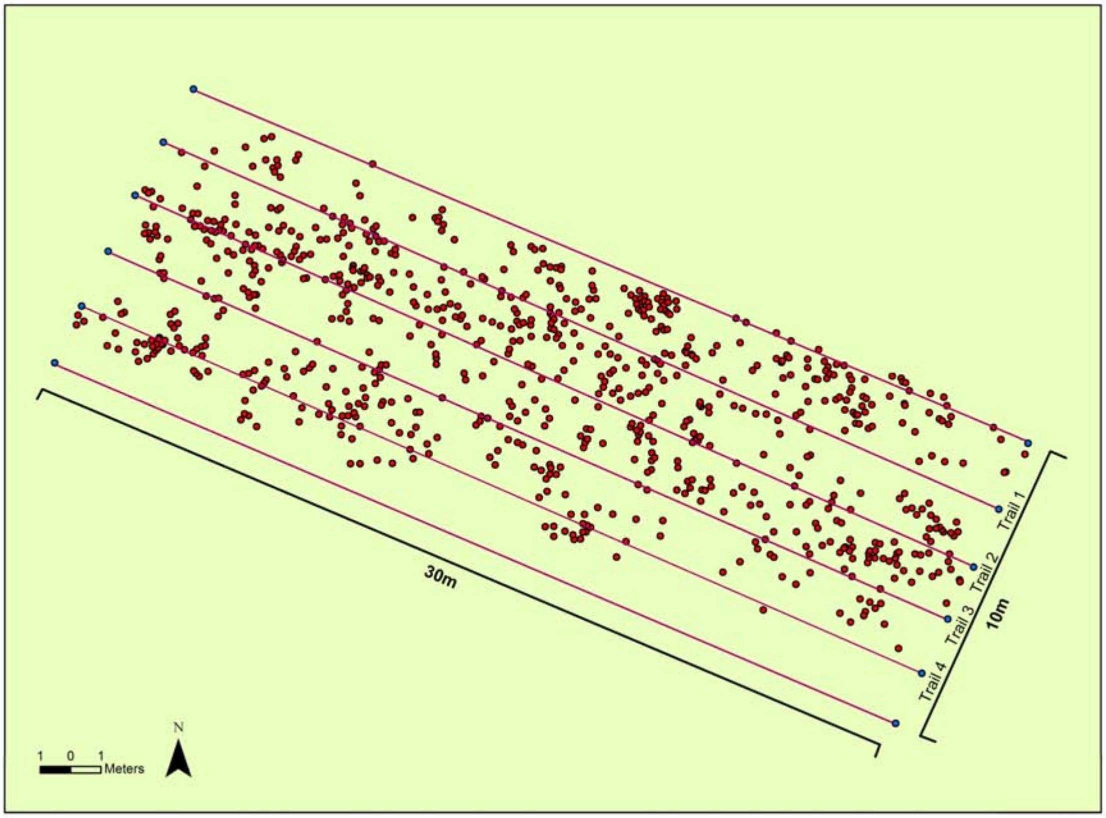


Figure IV-3. Evidence and search trail distribution in *Exercise 3*. Effective search area in each trail was estimated in around 150 m^2 in all corridors, based on the effective search distances obtained with *Distance* 6.0. See text for further explanations.

Plotless Methods: Estimating Evidence Density before Scene Processing

Distance, Line-Transect sampling or, more generically, *plotless methods* (Buckland *et al.* 2001) are typically employed to estimate the density of moving animals or, more relevant to this study, inanimate objects, such as bird nests, mammal burrows, or animal carcasses. From a forensic point of view, they offer several advantages that can be very useful in the early processing of a mass disaster scene. The primary benefit is that they allow the researcher to obtain reliable density estimates with minimum personnel and in a very rapid manner, which makes them very appropriate for preliminary scene assessments. Their parametric requirements also fit the conditions in forensic mass scenes as, unlike other spatial analysis methods, they do not assume that the items are randomly distributed within the search area (this is to say, that evidence density follows a Poisson distribution), which is expected to be the case in crash or bomb scenes, where evidence density decreases with distance to the focal point of impact or explosion. Finally, these methods allow for variability in the detection rates of the observers, as the estimates are not based on item counts (as in the plot methods described below), but rather on the distances of the detected objects from the reference line.

The mathematics of these methods is somehow complex, but their rationale is very intuitive. The parameter that we are trying to estimate is evidence density, expressed as the number of evidentiary items per unit area. If we consider a single searcher, moving along a straight line of length L, the searched area (A) will be equal to this length multiplied by two times the distance (w) in which the searcher is able to detect an evidentiary item or:

$$A = 2wL \tag{1.1}$$

If the searcher were able to detect every single evidentiary item in the search area (A), our density estimate (D) would become:

$$\hat{D} = \frac{n}{2wL} \tag{1.2}$$

Where n is the total number of items detected.

However, our observer will be less likely to detect objects that are farther away from her, than those lying directly on her path. Thus, we will need to correct for this factor by multiplying w by a function [$P(a)$] expressing this decreasing probability of detection with distance from the observer (i.e. from the central search line):

$$\hat{D} = \frac{n}{2wL\hat{P}(a)} \tag{1.3}$$

The probability density function (pdf) of perpendicular distances to detected objects, denoted $f(x)$ is inversely proportional to the decrease in probability of detection with distance ($wP(a)$). This is to say, the average distance to the line of all detected objects will be inversely proportional to how frequently we are able to detect increasingly distant objects. If distant objects are still easily detected (the rate of detection decrease with distance $P(a)$ is small), the average distance to the line of all the objects we detect will be large. Assuming that the probability of detection at distance 0 is equal to 1 (i.e. that the observer will find all objects falling directly at her feet), the problem is reduced to modeling *f(x)* and evaluating the fitted function at *f(0)*:

$$\hat{D} = \frac{n\hat{f}(0)}{2L} \tag{1.4}$$

Simplifying, the method is based on the estimation of a *detection-on-distance curve*, which can be visualized as a decay function reflecting the decrease in items detected with distance (see Figure IV-5 and Figure IV-6 in the Results section below). An extremely useful property of this detection function is that it serves to correct both for the detection ability of a particular observer and for interobserver differences. In other words, if the detection curve decreases very fast with distance from the line, the method will not assume that there are more items close to the observer, but that the observer is missing many objects farther away, and thus differences in visibility or observer ability will be taken into account and corrected. Arguably, these methods are even more accurate than the exhaustive search methods applied to search and process mass scenes, which are akin to the plot methods described below (Engeman and Sterner 2002).

The present study sought to assess the efficacy and applicability of these distance sampling techniques under conditions typical of mass disaster scenes. With this purpose, four parallel search lines were defined and marked with nylon string in each of the experimental areas described above (Figure IV-2 and Figure IV-3 above). Even when distance methods do not require search lines in the same area to be parallel or follow any particular orientation, this design was simply intended to allow for several of these exercises to be carried out concurrently, without overlapping search areas, thus allowing for a larger number of replicas per exercise.

In the first two exercises, secondary strings were ran parallel to the search string, in order to define a distance of 2 m at each side, and the searcher was asked to ignore any items beyond these boundaries. Under this design, the 2 m distance sought to approximate a fixed value for the effective search distance (w) in equations (1.1) to (1.3) above. This limitation was removed in the final exercise, calculating w directly from the distance data. In a real situation, this approach would reduce processing times, by eliminating the times required to mark and define the search boundaries.

Following scene preparation, a crew of Mercyhurst AFS students was familiarized with the general appearance of the mock evidentiary items, and each student was asked to perform a distance search. In these searches, a student walked through the corridor alongside the 30 m string looking for plaster items. A couple of students followed the searcher flagging all items identified by the first student. The assistants were instructed to avoid providing any guidance to the searcher, simply marking all objects observed by the later, independently of whether they were evidentiary items or extraneous objects not related to the exercise. Another two students followed noting the number of the detected items, whose location had already been determined (see above).

In this study, a total of 53 of these distance searches (13+26+14) were performed along 10 different corridor lines and carried out by more than a dozen different individuals.

Perpendicular distances to the search line were estimated from the total station or GPS point data in *ArcGIS*, and distance data were analyzed using the software *Distance* 6.0 (Thomas *et al.*, 2010.) Item densities were estimated through Variable Area Transect Methods (VATM), with bootstrapped confidence intervals (Buckland *et al.* 2001, Engeman and Sterner 2002, Engeman *et al.* 2005.)

Buckland *et al.* (2001) is the standard reference for distance sampling. Thomas *et al.* (2002) provide a briefer but comprehensive discussion, while Marques (2009) provides an abbreviated non-technical introduction to the technique.

Plot Methods: Assessing the Amount of Evidence remaining after Initial Scene Processing

The logic underlying plot methods is even more straightforward than that of plotless methods, and they do not require the application of any new searching techniques, but rather keeping track of the evidence detected and removed in different areas as the recovery effort progresses.

In a nutshell, the idea behind plot methods is that the evidence left at the scene can be estimated as a function of the amount of evidence recovered in consecutive searches. In its simplest formulation, if in our second search of an area of the scene we have recovered 10% of the evidence that we had recovered at an earlier search of the same spot, it is reasonable to expect that the evidence still remaining at this area would also be approximately 10% of the amount recovered in the second search (i.e. 10% of 10% = 1% of the amount of evidence originally recovered). In other words, under the simplest model we would be just assuming that in each search we are missing a constant fraction (10% in our example) of the evidence present at the scene.

Mathematically, let's say that during the first search, the crew recovers a number n_1 of items, which is a fraction of the total number of items present at the scene (N). The fraction of items that we missed during the search ($1-p$) is:

$$1-p=\frac{n_1}{N} \tag{2.1}$$

As we start a second search, the amount of items remaining at the scene after our first search will be:

$$N_2 = N - n_1 \tag{2.2}$$

During our second search, we recover a number n_2 of items. Now if we assume that $1-p$ is constant, and thus we are always missing a constant fraction of the elements present at the scene at any given moment, we have:

$$1-p=\frac{n_2}{N_2}=\frac{n_1}{N} \tag{2.3}$$

The original densities, N and N_2 are unknown, but we can estimate $1-p$ from (2.3) solving for:

$$1-p=\frac{n_2}{n_1}=\frac{N_2}{N}\Rightarrow N_2 = N\frac{n_2}{n_1} \tag{2.4}$$

We want to obtain an estimate of N, which we can obtain from the equation system configured by (2.2) and (2.4):

$$\begin{cases} N_2 = N - n_1 \\ N_2 = N\dfrac{n_2}{n_1} \end{cases} \Rightarrow N - n_1 = N\frac{n_2}{n_1} \tag{2.5}$$

Solving for N:

$$\hat{N} = \frac{n_1^2}{n_1 - n_2} \tag{2.6}$$

Therefore, our estimate of the amount of evidence left at the scene after our two searches will be:

$$\hat{N} - n_1 - n_2 = \left(\frac{n_1^2}{n_1 - n_2} \right) - n_1 - n_2 \tag{2.7}$$

The intuitive estimate in (2.6) is also the maximum likelihood estimator (MLE) for *N* (Borchers *et al.* 2004). We can also estimate the probability of detection (*recovery rate*), whose MLE coincides with the solution for *p* in equation (2.4):

$$1 - p = \frac{n_2}{n_1} \Rightarrow \hat{p} = 1 - \frac{n_2}{n_1} = \frac{n_1 - n_2}{n_1} \tag{2.8}$$

This methodology is known as a *plot sampling removal method for density estimation* (Borchers *et al*. 2004). These methods have been in use and thoroughly tested in field ecology and other fields for several decades (see Schwarz and Seber 1999, and references therein, for a thorough review of the past century literature). The MLE for the two-search model can be easily generalized for a larger number of searches by substituting the equation-system (2.8) by:

$$\begin{cases} 1 - \dfrac{n}{\hat{N}} = \left(1 - \hat{p}\right) \\ \hat{p} = \dfrac{n}{\sum_{s=1}^{s} R_s} \end{cases} \tag{2.9}$$

Where n is the total number of detections, s the number of searches, and R_s the number of items removed before search s.

When the number of searches is large, the parameter p in equation (2.8) can be calculated for each pair of successive searches, and regressed for the pooled sample against the average weights of the evidence recovered in the corresponding searches (Motulsky and Christopoulos 2004). This would allow for the estimation of the effect of item size on detection rate.

Application of the same method in real situations will hopefully allow for the assessment of, not only the amount of evidence still present at the scene, but also its expected average size, an important factor when deciding whether the scene should be released (items under a given size range may be considered undetectable or unrecognizable as human remains or disaster trophies).

The method allows for the calculation of variances and the corresponding confidence intervals for p and N. Generalizations of this basic model exist to account for non-constant values of p, based on item characteristics, such as size class or evidence densities, or on factors such as search effort (e.g., search crew size and deployment time). This study proposed testing different models, in particular *Change-in-Ratio* methods (Borchers *et al*. 2004), with bootstrapped confidence intervals (Borchers *et al.* 2004, Davison and Hinkley 2007, Manly 1997), which are considered to have high potential to estimate evidence density, recovery rates, time to completion of scene processing, or the optimal amount of personnel required to complete the recovery. However, as will be described below, the observed recovery rates were so high, both in mock bomb blast scenes and in the Missouri-style exercises that they would not allow for further comparisons or analyses past the simplest model described in equation (2.7). However, due to their immense potential and ease of application in real situations, we kept their general theoretical outline and rationale description in this section.

Recovery rates were assessed through this method for the three experimental corridors and two of the bomb exercises in the study. In this way, successive line searches, with crews of searchers advancing through the corridors shoulder to shoulder were repeated until detection rates approached zero. These searches were discontinued in further exercises, due to the extremely large recovery rates observed, which made any further calculations irrelevant.

Results

Plotless Methods: Estimating Evidence Density before Scene Processing

The exercises showed that distance sampling, having a single observer identifying objects while waling across predetermined straight lines can be accomplished in a quick and efficient manner, rendering reliable estimates of the amount of evidentiary items present at different areas of the scene. In the final exercise, after the distance search protocols were refined and definitively determined, and utilizing an R8 GPS unit, the average time to complete one of these searches, including spatial data collection, was around half an hour (32 ± 7 minutes). This was attained with minimal training of the searchers, most of whom where performing this type of search for the first time.

A lateral bias was generally present, with the searcher detecting more items at one of their sides (Figure IV-4). This asymmetry seems to be very correlated across observers and within search efforts and corridors, also switching from right to left in different corridors and exercises. This suggests that it may related with visibility conditions, depending on grass height, light angle, etc., rather than with human laterality, which is more predominant for the right side. Even when this did not seem to affect the obtained estimates (see below), it points toward the convenience of setting the distance search lines following random orientations at the scene. In particular if more complex analyses are intended, such as the estimation of gradients of evidence density with distance to the central explosion or impact point. In other words, searchers should not advance following the same direction (e.g. North-South) in all cases.

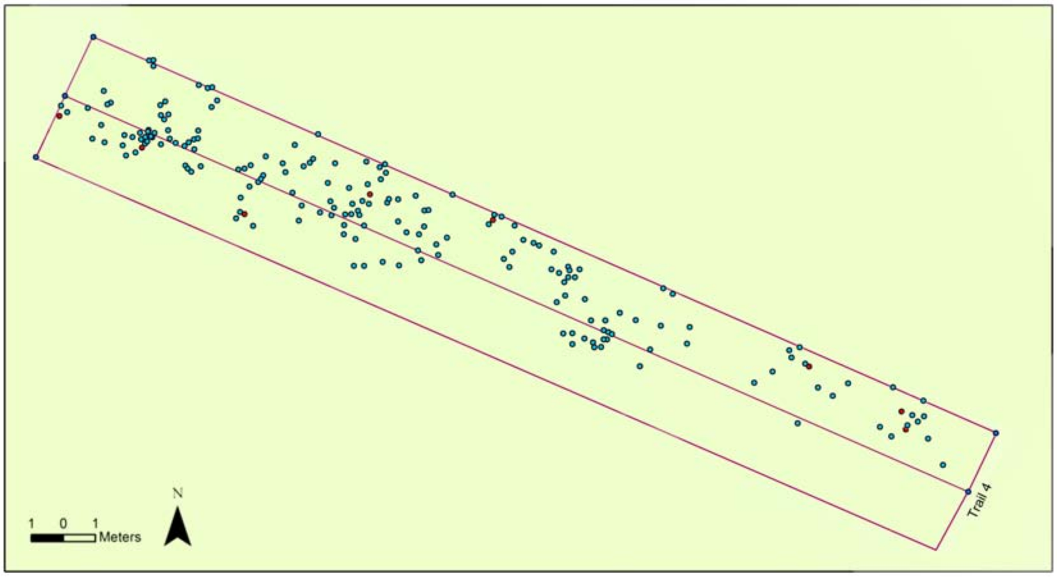


Figure IV-4. Items detected by one of the observers in one of the search corridors of Exercise 3, demonstrating asymmetrical detection favoring the items placed at one of the sides of the observer (usually the right side). The observer advanced from Southeast to Northwest (right to left in the figure). These asymmetric rates of detection did not seem to affect the density estimates, but random placement and orientation of the search lines is recommended to avoid potential biases due to this factor.

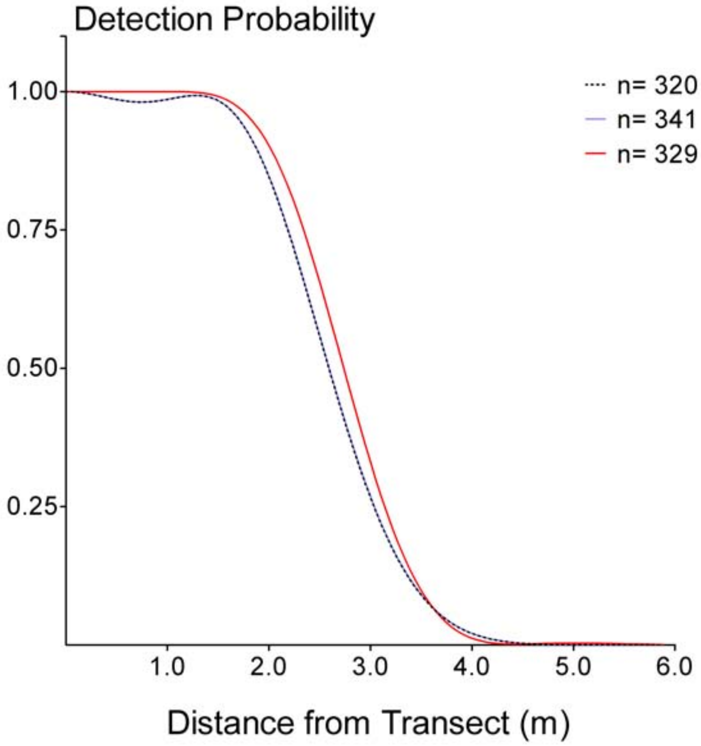


Figure IV-5. As predicted by the model, individual differences in detection abilities had minimal impact on the estimates, resulting in very similar detection probability functions across individuals for any given search trail. Note how in this trail, from Exercise 3, the detection probability functions of the two individuals displaying the highest and lowest detection rates are virtually identical.

Secondly, the high detection rates also indicate that effective search distances (w) should not be fixed in less than two or three meters, as otherwise the detection probability functions would tend to result in monotonic straight lines with small slopes, as the perceived decrease in detection rates with distance would be very small. In other words, as explained above, the method uses the decrease in detection rates observed as the distance of the object to the line (i.e. the observer) increases. If such a decrease is not observed, or is very small, the method will be less efficient fitting the corresponding function, and therefore correcting for this factor (and individual observer ability) when estimating densities. The effective search distances estimated in *Exercise 3* (when w was not strictly fixed, as explained above) were around five meters in all cases, suggesting a recommended distance of 2.5 to 3.0 meters at each side of the central search line, when this is fixed by marking the search trail boundaries with string. This would be recommended in scenes with high densities of evidence, such as that expected in proximity to the center of impact or explosion, before the area has been processed. In this case, fixing and marking the boundaries beyond which the searcher should ignore any present evidence, would reduce search times derived from the overwhelming amount of elements present at the area.

However, the consistency of the effective search area and density estimates obtained in the study suggests that, in areas with low densities of evidence, such as those having been already processed following the recovery protocols (and thus where most evidence has been already removed), or located close to the external boundaries of the scene, determining and marking the search corridor boundaries is unnecessary. Basically, the search team should decide on a per-case basis, based on the trade-off between the time necessary to measure and fix the string boundaries, and that may result from recording the amount of material present at longer distances.

On the other hand, small deviations in the shape and dimensions of the effective search area, related to factors such as the wind or other natural agents reducing the tension of the marking strings, or the rapid method of string placement selected, did not result in significant alterations of the density estimates, with all effective search distances obtained through the analysis coming extremely close to both the initially intended ones and those measured in the field. Based on this observation, delimiting and marking the search boundaries can be accomplished in all cases in an extremely fast and easy manner. It suffices measuring the desired distance (e.g. three meters) at each side of the initial and final ends of the line marking the central search path, placing a chain pin at each of these four points, and joining them, two by two, with two pieces of nylon string. This results in small local deviations of the fixed distance or the central location of the search path but, as mentioned, this will not affect the density estimates significantly.

Table IV-1 displays the density estimates obtained from the 14 searches performed in *Exercise 3*, applying the protocols in their final form. When single individual searches were considered to produce the final density estimate, six out of the 14 searches, or 43% resulted in confidence intervals not containing the real number of items present at the scene (800 items for an average density of 2.67 items/m^2). This figure is actually not significantly different from the 0% probability of random chance. However, only two of the individual searches resulted in gross underestimates (more than 100 items less than actually present at the scene) when the upper confidence limits are considered, with all of them rendering maximum estimates of 630 elements or more. This extreme is particularly relevant, as the main concern in a real situation would be grossly underestimating the amount of evidence present in a section of the scene, resulting in an inefficient assignment of resources or over-optimistic assessments of the time and personnel required to complete scene processing.

Table IV-1. Density estimates obtained in the 14 searches in *Exercise 3*, applying the definitive refined protocols. The real number of items present at the scene was 800. Those cases in which the real density fell outside the estimated confidence intervals are noted with an asterisk (*). Note how a single individual (KMW, shadowed cells) was responsible for 50% of the inaccurate estimates, suggesting that searcher ability may play a role when a single search is examined. However, also note how when the data from the four searches performed by this same individual are combined, the resulting estimate is both accurate and precise (739 items, as compared to the 800 that were really present at the scene).

Observer	Line	N Estimate	95% Conf. interval		Error	% Error
CCJ	1	1102	1027	1182	302*	37.8
KMW	1	585	490	700	-215*	26.9
SMF	1	923	776	1098	123	15.4
DDR	2	963	817	1135	163*	20.4
KMW	2	892	772	1031	92	11.5
MEK	2	846	783	915	46	5.8
SMG	2	857	792	927	57	7.1
CEM	3	766	589	996	-34	4.3
ENC	3	766	590	995	-34	4.3
KMW	3	513	374	704	-287*	35.9
LLC	3	719	547	945	-81	10.1
SMF	3	704	538	922	-96	12.0
ARG	4	568	511	630	-232*	29.0
KMW	4	569	472	687	-231*	28.9
SMF	2 Lines	712	617	822	-88	11.0
KMW	**4 Lines**	**739**	**599**	**914**	**-61**	7.6

Therefore, these results strongly suggest that even density estimates obtained from a single search (of around half an hour and by three or four individuals), can already provide reasonable and useful assessments of the amount of evidence present at a particular area of the scene. Given the low time and personnel requirements of these searches, this would make them extremely useful in the first stages of scene processing and, particularly, in the initial planning and organization of the recovery efforts.

However, data from different searches should be combined to obtain more reliable density estimates. This is better done when the data combined correspond to the same searcher, but combination of data from different searchers also improves the estimates obtained from single-search calculations. Table IV-1 displays a particularly clear example of this observation. Three out of the six (50%) inaccurate estimates discussed above corresponded to individual searches performed by the same individual (KMW). This seems to indicate that the searcher's ability does play a role in the accuracy of the estimates based on a single search. However, when the four searches of this individual are combined (Figure IV-6), including the three inaccurate ones, the estimate obtained is one of the most accurate ones in the table (730 items, for 800 really present at the scene, with a confidence interval from 599 to 914 elements). The reason for these discrepancies, and the superiority of estimates obtained from multiple searches, is derived from the same function-fitting problem described above for small effective search distances. Namely, when only one search is entered in the analysis, the detection probability function must the fitted to a single monotonic function, thus losing detail. The combination of data from more than two searches allows for more alternatives and better fits. In this study a half-normal model with a cosines approximation method (one of the simplest ones, and the one offered by default by the software *Distance 6*) showed to produce good estimates.

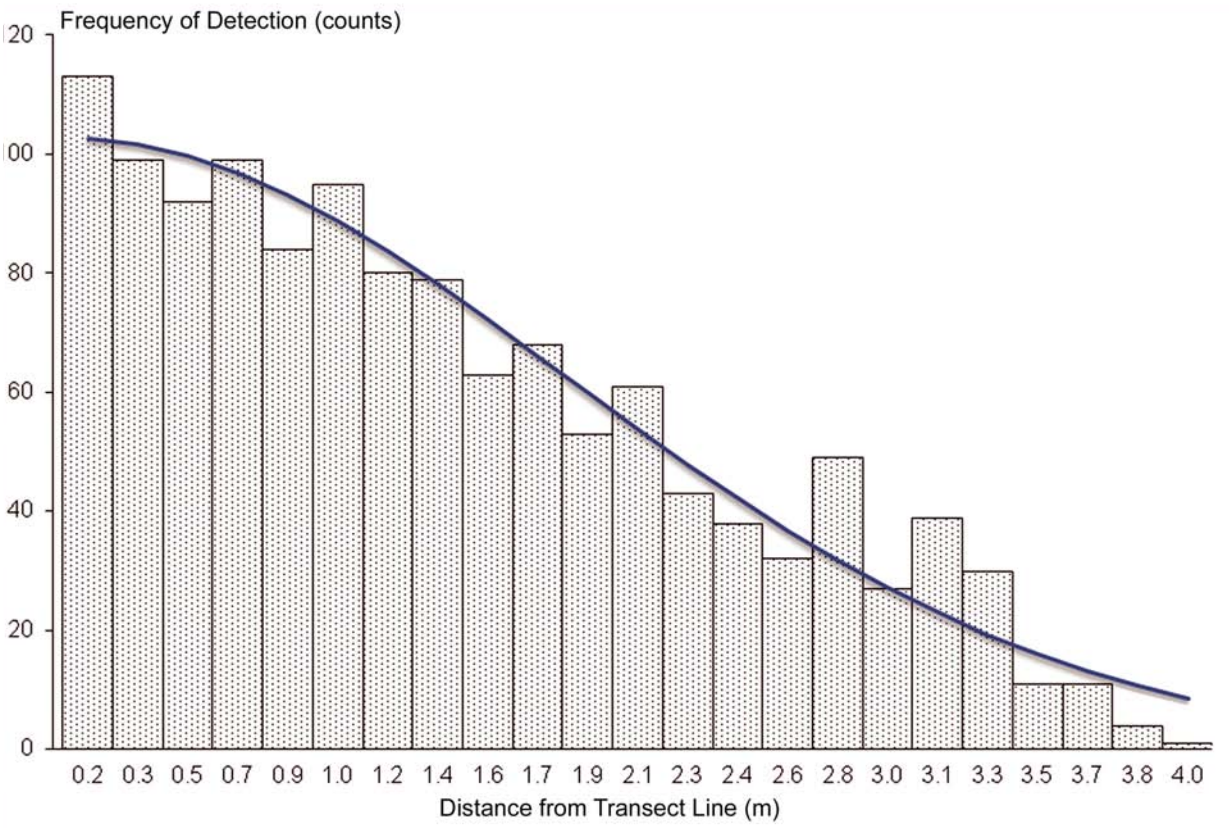


Figure IV-6. Detection probability function, obtained from four searches by a same individual. Note the inflexion point at distances around two meters. Estimates based on shorter distances would miss this tendency change.

From a practical point of view, this results in the recommendation to perform at least three or four searches in each area, by the same observer and along search lines randomly placed following different orientations (see above), whenever possible. Then again, we must remember that the data from each individual search can already serve to provide a good assessment "on the go," if they can be transmitted or processed directly at the scene as new searches are being performed. Areas with low densities, such as those at the outer limits of the general scene, or which are being surveyed in order to decide their potential release, would probably require a minimum of four of these searches, depending on time availability and the topography of the area.

Plot Methods: Assessing the Amount of Evidence remaining after Initial Scene Processing

Density estimates through plot methods were assessed by performing successive line searches with teams of ten members, spaced at arm-length distance, once the plot-less searches or bomb exercises had finalized.

In general terms, under the experimental conditions, the plot, capture-recapture methods resulted largely irrelevant due to the extremely high recovery rates obtained during the conventional forensic line searches. Actually only one of the 4 searches of this type performed across exercises required more than two searches to recover all evidentiary items, showing recovery rates above 95% in all cases. The only exercise requiring more than two successive forensic line searches to recover all elements was the first search of *Exercise 1*. In this case 482 out of 500 elements (96%) were recovered in the first search, seven in the second and four in the third, resulting in seven (1.4%) not located or recovered in two additional searches. Similar sharp decreases in the evidence located from the second search were also observed in the mock bomb scenes, under more realistic conditions.

Therefore, when sharp decreases like these are observed in successive searches (in the range of the second search rendering less than 5% of the items recovered in the first one), equation (2.7) above, based on the last two searches, can already provide a reasonable estimate of the materials remaining at the searched area, without any apparent need to test more complex models. For example, in the case of the search described above, with n_1 = 482, n_2 = 7 and n_3 = 4 (with n_i representing the number of items recovered during the ith search), our calculation after the first two searches would become:

$$\frac{n_1^2}{n_1 - n_2} - n_1 - n_2 = \frac{482^2}{482 - 7} - 482 - 7 \simeq 0 \tag{2.7}$$

Or, in other words, the estimation would suggest that no more items remain at the scene. However, the estimate is more useful once we reach lower densities. This is to say, when we have performed a third search to get sure of the scene being completely clean. In this case:

$$\frac{n_2^2}{n_2 - n_3} - n_2 - n_3 = \frac{7^2}{7 - 4} - 7 - 4 \simeq 5.3$$

This estimate suggests that around five evidentiary items are still present at the scene and another search is in order. This figure is very close to the seven items actually remaining at the scene at this point. When the estimate approaches zero, or we do not find more items in a search, we can reasonably assume that the items remaining are virtually undetectable. As discussed above, in the present study this never required more than three searches, and in most cases the first two searches served to recover 100% of the evidentiary items.

The same strategy and calculation will be useful if lower recovery rates are observed. This is to say, if the second search still renders a high number of items, well above 5% of the initially recovered. Basically, equation (2.7) will perform better the closer n_1 and n_2 are.

Item size, as expected, also played an important role. The average weight of the seven items missed in the search above was less than 0.4 g, with the largest item missing weighing just seven grams. As an example, human tissue samples around these sizes would be extremely difficult to spot and, even more importantly, would degrade very fast under natural conditions.

CHAPTER V

CONCLUSIONS

Discussion of Findings and Implications for Policy and Practice

Research Component 1

Equipment suggested for use in a mass fatality recovery effort is affordable, highly customizable, and has a high amortization. The protocols favor equipment that is already available to law enforcement for other duties over equipment that is specifically suited for mass fatality scenarios. Also, equipment that could be incorporated into everyday practice was favored over specialty devices with little utility outside of the mass fatality scenario. Lastly, equipment that was easy to maintain and operate for the user was favored over more complex counterparts. The equipment detailed in each configuration has the ability for multiple uses for agencies both big and small. This cross utilization of product eliminates superfluous, specialized equipment. The configurations are expandable to customize a set-up for agencies of all sizes without losing functionality.

All pieces of equipment in the configurations have steep learning curves, adding to their utility in the field and in every day operations for all types of agencies. In this way, multiple personnel can become proficient with several pieces of the equipment, thus adding to the equipment's utility in the field and in everyday practice.

Research Component 1 demonstrated that recordation of all spatial data, including contextual information, can be collected in a timely manner without adding significantly to the overall recovery effort. This configuration allows for more efficient scene management, readily identifying searched and critical unsearched areas, and even the amount of evidence recovered or expected at the area. GPS units can also be used as a substitute for compasses during searches or initial scene inspections, allowing for much more precise initial scene sketching, and even direct real time transmission to the central computer in the command center.

Research Component 2

Separating personnel into individual teams allows for each team to work autonomously thereby increasing productivity. The most time intensive aspect of the recovery effort was photography, as revealed by bottlenecks in which the Collection Team was iddle, waiting for the photography team. Consequently, two Photography Teams per recovery unit were introduced, resulting in an increase in productivity not jeopardizing the integrity of the barcoding system, which was set-up to allow only unique entries (no overlap in barcodes).

As discussed in the conclusions in *Research Component 1*, the learning curve for each piece of equipment is steep. Once the Provenience Team adjusted to the team dynamic, spatial points could be collected with the total station at an average of 30 seconds per point. Using the survey-grade GNSS, this rate was reduced to an average of 10 seconds per point. The expedited times did not effect recovery rates, which successfully identified and collected greater than 90% of material (as discussed in *Research Component 3*).

Research Component 3

Research Component 3 exemplifies the applicability to assess the amount of evidence remaining at the scene at each moment, and its spatial distribution (based on estimates for each search area) in real scenes and in real time. Distance sampling methods are very promising as a cost-effective, quick method for scene assessment, requiring minimum personnel, and being very robust for inter-observer differences or anisotropic distributions.

Plotless methods can be utilized when the initial search is reasonably effective, and does not require excessive scene post-processing. The methods can be applied to the spatial data as they are recorded, during regular recovery, and thus will not add additional tasks to the protocols (in a sense, they are effort-free, following protocol implementation). Both density methods can be extremely useful for scene management, helping to decide which areas require further processing, or may be released with minimum risks. The estimates can even be readily extrapolated to unsearched areas, if they are contiguous with processed ones (Borchers 2004, Buckland *et al.* 2001). It is also possible to estimate the number of searches necessary to attain a recovery rate under a certain value. Finally, and interestingly, the availability of count points (spatial data) and density estimates opens the door to modeling factors such as explosion dynamics, which could help better establish search parameters, or spatial association of evidentiary items, which in turn could aid in establishing identity.

Implications for Further Research

With the protocols established, along with data acquisition, management and storage, future research should focus on better inter-connectivity in the field for real-time updates and reports throughout the recovery efforts. There is also a need for better intra-connectivity between the field and the disaster morgue. This could be established with newer technologies and the utilization cloud computing.

Newer technologies could also be used in the field for better documentation and on-site analyses. In the event of a confined crash site, three-dimensional scanners can be used to scan the scene and estimate the volume of the debris field, which in turn, will help with personnel and needs cost assessments necessary for a particular site.

The plotless methods used in *Research Component 3* can also introduce and analyze other parameters. Cluster size can be examined to estimate the dispersion of remains from a single individual to possibly aid in identification. Also, the recognition of gradients from the crash site may help detect or predict where remains are likely to be found, as well as areas that do not require further processing.

Lastly, more protocols need to be developed for other potential scenarios. As shown in *Research Component 1*, different scenarios, like the condensed crash site of Clarence Center, NY, and dispersed crash sites, such as Flight 93, require slightly different recovery protocols. Scenarios such as a plane crash in an urban environment, or natural disasters such as tornadoes, remain to be investigated with specific protocols.

CHAPTER VI

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CHAPTER VII

DISSEMINATION OF RESEARCH FINDINGS

Funding from the NIJ has afforded the investigators of this project the opportunity to disseminate information on effective and efficient scene processing protocols for mass disaster incidents to a large number of law enforcement, forensic investigators, and coroner/medical examiner office personnel. Dissemination efforts throughout the project duration included yearly short courses, special workshops, training exercises, and lectures at regional and national meetings. Table VI-1 below highlights the major dissemination milestones accomplished during the project period. These dissemination opportunities also provided the impetus for testing subsequent modifications to the *Weldon Spring Protocols*, which in turn, provided the foundation of the research described here.

The most significant testing and dissemination efforts occurred during the post-bomb blast recovery exercises conducted both during the Post Blast Recovery Short Courses presented yearly at Mercyhurst College and the additional training and research exercises permitted by the grant. During these exercises testing and refinement of the *Weldon Spring Protocols* was conducted but also provided an opportunity for participants to get hands-on experience in actuating the recovery protocols. These training exercises permitted the effective dissemination of information to law enforcement (including FBI), federal agencies (including NTSB), and other state and local agencies participating in the exercises. A great deal of feedback was obtained from the exercises that helped in the production of the final scene processing protocols included in this report.

Scene processing and the recovery of the victims of Continental Flight 3407 in February of 2009 afforded the investigators of this project the opportunity to employ and test the recently established recovery protocols in real scene conditions. The investigators had the chance to refine pre-disaster planning, recovery efforts, and collaboration with other crucial investigating agencies (FBI; NTSB; local Medical Examiner's office; fire fighters; etc.). Modifications were made to the protocols based on information gleaned (confined area mass disaster versus large scale). The investigators of this project garnered useful knowledge from working with other national agencies on large-scale disaster scenes.

In addition, descriptions of the project, protocols and results have been presented at regional meetings including the annual Kentucky Coroner's Convention in Louisville, KY; the annual New York coroner's convention in Rochester, NY; the annual Michigan Medical Examiner's meeting in Mt. Pleasant, MI; Region V DMORT training in Kokomo, IN; the Medicolegal Death Investigation Course for new Pennsylvania coroners in Hershey, PA; the North East Forensic Anthropology Association (NEFAA), NIJ focus group in Alexandria, VA; Ontario Police College, Alymer, ON.

The research has been highlighted in presentations at the national level including the annual National Meeting of the National Association of Medical Examiners (NAME) in San Francisco, CA; the American Academy of Forensic Sciences (AAFS) in Chicago and Seattle; American Association of Physical Anthropologists (AAPA) in Minneapolis, MN; NIJ Conference in Arlington, VA; NIJ's Syracuse University Dialogues in Forensic Sciences, Syracuse, NY; and the Dungarvan Global Intelligence Forum, Dungarvan, Ireland.

Descriptions of the protocols have also been presented in a chapter on mass disaster (*Forensic Anthropology at the Mass Fatality Incident (Commercial Airliner) Crash Scene* by DC Dirkmaat) and in the soon to be published book *Companion to Forensic Anthropology* (DC Dirkmaat, editor).

It is the intention of the investigators to continue to publish and distribute all information gleaned from this project, including: scene processing protocols, technology integration and technological configurations. This information will be distributed to law enforcement, forensic investigators, medical examiner's/coroner's offices, and all other agencies involved in the handling and processing of the mass fatality scene throughout the country.

Table VI-1: **Major Dissemination Milestones for this Research Project**

Date	Description
22-26 June 2009	*Wattsburg, PA.* Post-bomb blast short course conducted by Mercyhurst College, Erie, PA. Recovery of (*Sus scrofa*) remains and physical evidence at the scene of a small car bombing. Tested revised *Weldon Spring Protocol* for the effective and efficient documentation and recovery of remains and physical evidence at the mass disaster scene. The short course served to test the new protocol configurations with volunteer participants from different law enforcement and first response agencies from across PA.
25 Aug 2009	*Aylmer, Ontario.* Day-long presentation and discussion on the specifics of mass fatality recovery protocols to the Ontario Provincial Police during an annual plane crash/recovery course at the local college. *Dennis C. Dirkmaat*
12 Sept 2009	*San Francisco, CA.* "Forensic Archaeological Documentation and Recovery of the Victims of the Continental Connection Flight 3407 Crash in Clarence Center, NY." Presented to the 43rd annual meeting of the National Association of Medical Examiners, 11-19 of September. *Dennis C. Dirkmaat, Dianne Vertes, Luis L. Cabo, Steven A. Symes, and Erin N. Chapman*
18-20 Sept 2009	*Williamsport, PA.* Two-day short course conducted in conjunction with *TripWire* Company. At this course, testing of revised protocols for the recovery of remains and physical evidence at the scene of a mass disaster was conducted. This week-long course tested protocols for the effective and efficient documentation and recovery of remains and physical evidence at the mass disaster scene.
20 Sept 2009	*Rochester, NY.* "Forensic Archaeological Documentation and Recovery of the Victims of the Continental Connection Flight 3407 Crash in Clarence Center, NY." Presented to the NY Medical Examiner's Conference, Rochester, NY. *Dennis C. Dirkmaat, Dianne Vertes, Luis L. Cabo, Steven A. Symes, and Erin N. Chapman*
Nov 2009	*Alexandria, VA.* "New Mass Disaster Scene Recovery Protocols." Presented at the Forensic Anthropolgy Grantees Focus Group. *Dennis C. Dirkmaat, Luis L. Cabo, and Erin N. Chapman*
Nov-Dec 2009	*Hershey, PA.* Organizer and lecturer, Pennsylvania State Coroner's Basic Education Training Course. A 40-hour course for newly elected Pennsylvania state coroners and deputy coroners. *Dennis C. Dirkmaat*
24-27 Feb 2010	*Seattle, WA.* Presentation entitled "Forensic Archaeological Recovery of the Victims of the Continental Connection Flight 3407 Crash in Clarence Center, NY", Proceedings of the 62nd Annual Meeting of the American Academy of Forensic Sciences. *Dennis C. Dirkmaat, Steven A. Symes and Luis Cabo-Perez*
22 Apr 2010	*Louisville, KY.* "Forensic Archaeological Documentation and Recovery of the Victims of the Continental Connection Flight 3407 Crash in Clarence Center, NY." Lecturer, at the Kentucky Coroner's Association Annual Meeting, Louisville, KY. *Dennis C. Dirkmaat, Dianne Vertes, Luis L. Cabo, Steven A. Symes, and Erin N. Chapman*
18-24 Apr 2010	*Hershey, PA.* Organizer and lecturer, Pennsylvania State Coroner's Basic Education Training Course. A 40-hour course for newly elected Pennsylvania state coroners and deputy coroners. *Dennis C. Dirkmaat*

1-5 June 2010	*Erie, PA.* Organizer and lecturer, annual forensic archaeology summer short course at Mercyhurst College. A one-week course on recovery at the outdoor crime scene sponsored by the Department of Applied Forensic Sciences.
14 June 2010	*Arlington, VA.* Lecturer, The National Institute of Justice Conference 2010. Presented mass disaster recovery protocols.
19 June 2010	*Syracuse, NY and Old Forge, NY*. Advances in Outdoor Scene Recovery: Looking Outside the Box (of Bones). Presented at the Dialogues in Forensic Science: Looking to the Future of Forensic Anthropology at the University of Syracuse.
21-25 June 2010	*Erie, PA.* Organizer and lecturer, annual post-bomb blast recovery summer short course at Mercyhurst College. A one-week course on processing the mass fatality scene sponsored by the Department of Applied Forensic Sciences.
12 July 2010	*Dungarvan, Ireland.* Lecturer, Mercyhurst College Global Intelligence Forum (Best Analytic Practices): The Dungarvan Conference. *Dennis C. Dirkmaat*
25 Feb 2011	*Chicago, IL.* Presentation entitled, "New Forensic Archaeological Recovery Protocols for Fatal Fire Scenes." Presented at the 63rd annual meeting of the American Academy of Forensic Sciences. *Dennis C. Dirkmaat, Luis L. Cabo, Michael Kenyhercz, Allison Nesbitt, Alexandra Klales, and Erin Chapman*
12-16 Apr 2011	*Minneapolis, MN.* Presentation entitled, "Taking advantage of spatial data: the utilization of density estimates to manage mass disaster scenes with commingled human remains." Presented at the 80th annual meeting of the American Association of Physical Anthropologists. *Luis L. Cabo and Dennis C. Dirkmaat*