A Comparison of Event Analysis and Multilinear Events Sequencing Techniques for Reconstructing Unique Phenomena

Ross M. Gardner, MA, CSCSA

Abstract: Event Analysis is a specific crime scene analysis method in use today. Its purpose is to objectively define what happened in alleged criminal events and in what order it happened. This article compares Event Analysis methodology to the analysis method known as Multilinear Events Sequencing (MES). MES is an established methodology used by safety specialists, failure analysts, and other scientists to evaluate unique and rare events. This comparison will effectively demonstrate that the two methods are one and the same in theory, process, and purpose.

Keywords: crime scene analysis, crime scene reconstruction, Event Analysis, Multilinear Events Sequencing, Daubert

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Crimes represent singularly unique events. No two crimes have the exact same data set leading to their development, they occur in different environments and of course all crimes are temporally disassociated. Granted, analysts can study trends in crimes using tools like the Crime Classification Manual [1], but the distinctions evident in trends, such as the differences noted between a domestic homicide as compared to a sexual homicide, does little to explain the actions of a specific criminal event. Once properly trained and experienced, the crime scene analyst is tasked with a responsibility to evaluate, study and reconstruct these unique incidents. They do this within the constraints of what is often referred to as the "archeologists dilemma" [2][3]. This dilemma is the recognition that the analyst is dealing with a historical incident and has only a small number of artifacts on which to base their conclusions about the incident. Like an archeologist, no one has all the pieces of the investigative puzzle; thus no one will ever have a complete picture of the incident. Operating within this environment, the crime scene analyst is expected to proceed in an objective fashion and provide a clear factual work product that can aid the judicial system in establishing guilt or innocence.

While immersed in the "archeologists dilemma", the analyst must also contend with the antagonistic nature of the judicial system. Lawyers from both sides of the table consistently attack any information that fails to meet their particular view of what the "truth" is. Although intended as measures to prevent "junk science" from entering the court, the various legal challenges such as Daubert, Shreck, or Frye are used as methods to effectively filter valid information from jurors. Unfortunately, the judges ruling on these concerns appear to be as much in the dark on the concepts of forensic science as the lawyers, which routinely leads to less-than-factual claims by lawyers being given credence. Of course these same lawyers use the reality of the "archeologists dilemma" as a bludgeon against the analyst, pointing out that what we know is often less than what we want to know. The bottom line for the forensic analyst is that no matter what the discipline, it will be attacked. It is not enough that the analyst can perform a forensic analysis; the analyst must be able to effectively defend their discipline.

This is the environment and situation that the crime scene analyst faces. In the face of this reality, this paper will compare two reconstruction methodologies. The intent is to show their similarities in an effort to aid the crime scene analyst in surviving any courtroom claim that the reconstruction resulting from a crime scene analysis is "unscientific".

The first method being considered is known as Event Analysis (EA). It was published as a technique in 1997 by the author and Tom Bevel [4]. Event Analysis was designed as a forensic technique to evaluate unique incidents believed to be crimes. The underlying themes that drive Event Analysis can be found in various criminal investigation references dating back as far as 1898, when Han Gross wrote the first true scientific investigative reference [5].

The second method of concern is known as Multilinear Events Sequencing (MES). MES was initially proposed by Ludwig Benner Jr. at the National Bureau of Standards in 1976 to evaluate unique and rare phenomena [6]. Since its publication, it has become an integral part of "failure analysis" studies and other similar reconstruction investigations. These include operations conducted by the National Transportation Safety Board (NTSB) and the Federal Aviation Administration (FAA). Subsequent to its initial description, MES technique has become an integral part of scientific investigations. It is currently described or referenced in numerous texts on system safety, failure analysis or accident investigation. More notable among these texts are Ferry's, Stephenson's and Hendrick's efforts [7][8][9]. Additionally, similar techniques have developed out of the MES process; this includes a technique known as Events and Causal Factor Analysis (ECFA) [10].

A Comparison of Theories

In 2007 the author and Tom Bevel wrote a paper outlining the theoretical basis of crime scene analysis as well as describing the Event Analysis process [11]. This theory, which had previously been described in a number of references, was simply: "Nothing just happens". A criminal incident is no different than any other historical incident. Every moment in history has a series of causal actions that lead to it and every moment in history has some series of actions that will follow it. By studying the debris of a crime and the context in which that debris is found, some of the actions associated with the incident and their order become evident. The noted physicist and crime scene analyst Edward Oscar Heinrich was the first author to effectively articulate this theory. In his biography The Wizard of Berkeley, he described his theory in a slightly more eloquent way, saying that when presented with crime:

> "One is confronted with scrambled effects, all parts of which separately are attributable to causes. The tracing of the relationship between isolated points of fact, the completion of the chain of circumstances between cause and effect are the highest function of reason." [12]

Event analysis is a crime scene analysis process, a technique utilized by the crime scene analyst to accomplish objective analysis. Thus the theoretical basis and underlying principles of crime scene analysis apply directly to Event Analysis.

In 1975 and 1976 Ludwig Benner Jr. published his theory of Multilinear Events Sequencing (MES) in two papers in the Journal of Safety Research [13][14]. MES was proposed as a process for accident investigation and rare event research that would remove both the hit and miss aspects of the typical investigative effort and provide a more effective technique for hypothesis generation. In describing the underlying theory Benner wrote:

> "My hypothesis generation method is based on the premise that the functioning of our universe and its constituent parts reflects a continuum of interacting events. Events, in this context, are used in the sense that someone or something does something (actor + action = event.) Each event influences one or more events, which follow that event in time. It is the precede follow logic of the related events that provides the key to the hypothesis generation method." [15]

Based on these descriptions it should be evident that EA and MES share the same underlying belief, actions are linked causally and temporally. A unique series of related actions lead to some ultimate act (e.g., a murder or a plane crash). Through detailed and organized study of these unique phenomena, some of these actions and their interrelationships will be identified. These techniques can never fully describe all aspects of the incident being studied, but proper application of this theory leads to a more effective understanding of what happened and the order in which it happened. In the case of safety research, this knowledge may prevent subsequent similar events. In the case of both safety research and crime scene analysis this information will ultimately aid those responsible for assigning blame for the act.

A Comparison of the Objectives of EA and MES

There is a simple objective in pursuing Event Analysis as a process. Crime investigations can be subjective by their very nature. This subjectivity exists for no reason other than human beings pursue the process. The nature of the subjectivity may be extreme, as in the case of confirmation bias or the interjection of personal prejudices in support of the investigative conclusions. Or it may be minor in form. A minor subjective example might be interjecting what the analyst considers to be a logical action into the analysis, to fill some gap, but for which, insufficient foundation in the form of physical evidence exists. Compounding this issue is the ever-present "archeologists dilemma" which always impacts the outcome of any analysis. To remove the potential subjectivity that humans bring to any situation, science defines methods and techniques grounded in the scientific method that guide the analyst. Event Analysis is such a technique; it focuses effort, refines the analyst's context and helps prevent the introduction of bad information, inappropriate assumptions, and or bias.

The ultimate outcome of correctly using Event Analysis is three-fold. First it assures the quality of the investigation and its final work product. If followed, it assures that the analysis will be achieved in the most objective fashion possible. In use, personal bias and experience become non-factors; the focus of the investigative effort is on describing actions that are based on physical evidence. The second outcome of Event Analysis is the work product itself, which is presented in as clear and unambiguous fashion as the data allows. At its core EA involves graphic representation of the crime using the Event Analysis flowchart. Lastly, the conclusions resulting from the analysis and flow chart provide everyone involved with an objective mechanism to evaluate more subjective investigative products. This is particularly true of testimonial evidence offered in the investigation and the various "theories" presented by suspects, police and lawyers to explain the criminal event.

The stated objective of Multilinear Events Sequencing is to ensure valid, effective investigative work products. It assures the quality of the investigation by focusing the efforts of the investigator, putting the collected data into a standard format, preventing the introduction of assumptions and presenting the conclusions in an objective and understandable format. MES also utilizes a graphic representation of the event, called the MES Tree or Matrix. Like Event Analysis, a stated objective of MES is "determining the quality of non-MES based work products. " MES in action is used to evaluate the more subjective aspects of any safety investigation or failure analysis.

In terms of ultimate objective, EA and MES share the same basic purpose. They provide a path to objective analysis and present the conclusions in an easily understood graphical format. Each of these techniques was designed to provide the analyst with an objective work product that can be used to check more subjective aspects of the investigation.

The Basic Investigative Unit for EA and MES

Both Event Analysis and Multilinear Events Sequencing operate around a basic investigative unit. Each seeks to identify as many of these investigative units as feasible, which in effect provides the detail of the analysis.

In Event Analysis the analyst ultimately defines the incident in question by identifying macro components known as "Events". Think of events as chapters in a book. Each "event" however is made up of discrete actions known as "event segments". The event segment is the true basic unit of EA. Think of an event segment as a snapshot from the incident, it defines an action that occurred during the incident. All effort is directed at defining these event segments. The more event segments defined, the more detail is known about the events. The more detail known about the events, the more the analyst knows about the overall incident. Event segments are always based on physical evidence and described as an action by some entity. This may be a human entity (e.g. Mary touched the wall after injury) or it may be some inanimate object undergoing change (e.g., the chair was knocked over). A temporal association of each event segment to the incident in question is an integral aspect of its definition. This temporal association means establishing the event segment's sequential and or specific time orientation to the incident.

MES operates on a nearly identical unit called an "Event Block". In MES the event block (EB) is defined as an actor plus an action and a time sequence. Actors include both human entities and or objects undergoing change. Note however that in MES a "time sequence" is not always a literal time (e.g., 10:02:02). Like Event Analysis, time sequence is a temporal association. It may be an estimated time, an actual observed time or a relative time (a sequential order).

A Comparison of EA and MES Process

Although described by very different authors, the functional process of achieving EA and MES hold significant similarity. This shouldn't be surprising, since both operate on the basic principle of scientific method.

As with all scientific method, the EA process begins with data collection. Using the data available, the analyst identifies as many discrete actions (the event segments) as possible. When an event segment is recognized, the supporting data is documented so it can be found and verified at a later point. The analyst then looks for related event segments. Once relationships are established between segments, the analyst attempts to order the event segments using both absolute chronology (the concept of a specific time) and relative chronology (the concept of sequential order). This latter chronology aspect is accomplished using three sequential tests. Every event segment is evaluated to define whether it: precedes, follows or is near simultaneous to some other segment. Although not ever action can be sequenced, as the sequencing of various segments is accomplished, the analyst begins to map out the incident. This involves literally drawing these sequential relationships. This map will become the Event Analysis Flowchart. It graphically depicts both the actions and the order associated with those actions. No analysis however presents itself as a complete or absolute picture of the incident; therefore, the fifth step of EA is to try and resolve any apparent contradictions that may appear within the data or flow chart. Depending upon the level of data available in a specific situation, resolution of contradictions may or may not be possible. Ordering of the event segments leads to crossover event segments, actions that correlate one event to another. Using this information the sixth step of the EA process is to revisit the events and validate their general order. The final step of EA is to validate the final Event Analysis Flowchart.

MES also starts with data collection. From the data the analyst identifies the event blocks (identifying an action and the actor). As each EB is identified, the analyst records the data source and then begins to organize the EBs. This is accomplished by applying both sequential tests and seeking cause and effect relationships between EBs. As these relationships are recognized the EBs are organized into a graphical format known as the MES Tree.

Of interest to both EA and MES techniques is the predicative value of each process. The resulting analysis is never a complete picture. As event segments or event blocks are identified, logical gaps in the graphic representation will become evident to the analyst. These gaps often result in the generation of new hypotheses whose purpose is to fill the gaps and link the known actions. Consideration of these hypotheses directs the analyst to revisit aspects of the available data for something that may have been overlooked and or to seek out new data in an attempt to locate evidence that might support or refute the hypothesis in question. This effort may or may not resolve the hypothesis; but if it is possible to resolve, then a more complete analysis results.

Data Sources Used in EA and MES

Event Analysis is based on data derived from artifacts found in the scene, the subsequent scientific analysis of those artifacts and the context of the scene itself. The preference in EA is that analysts not include testimonial evidence as a data source; however, EA recognizes that on occasion testimonial evidence may be the only source for describing the condition of an artifact or the scene at some point in time. If a testimonial source (e.g., a first responder) is considered objective and had the ability to accurately observe the condition of a scene

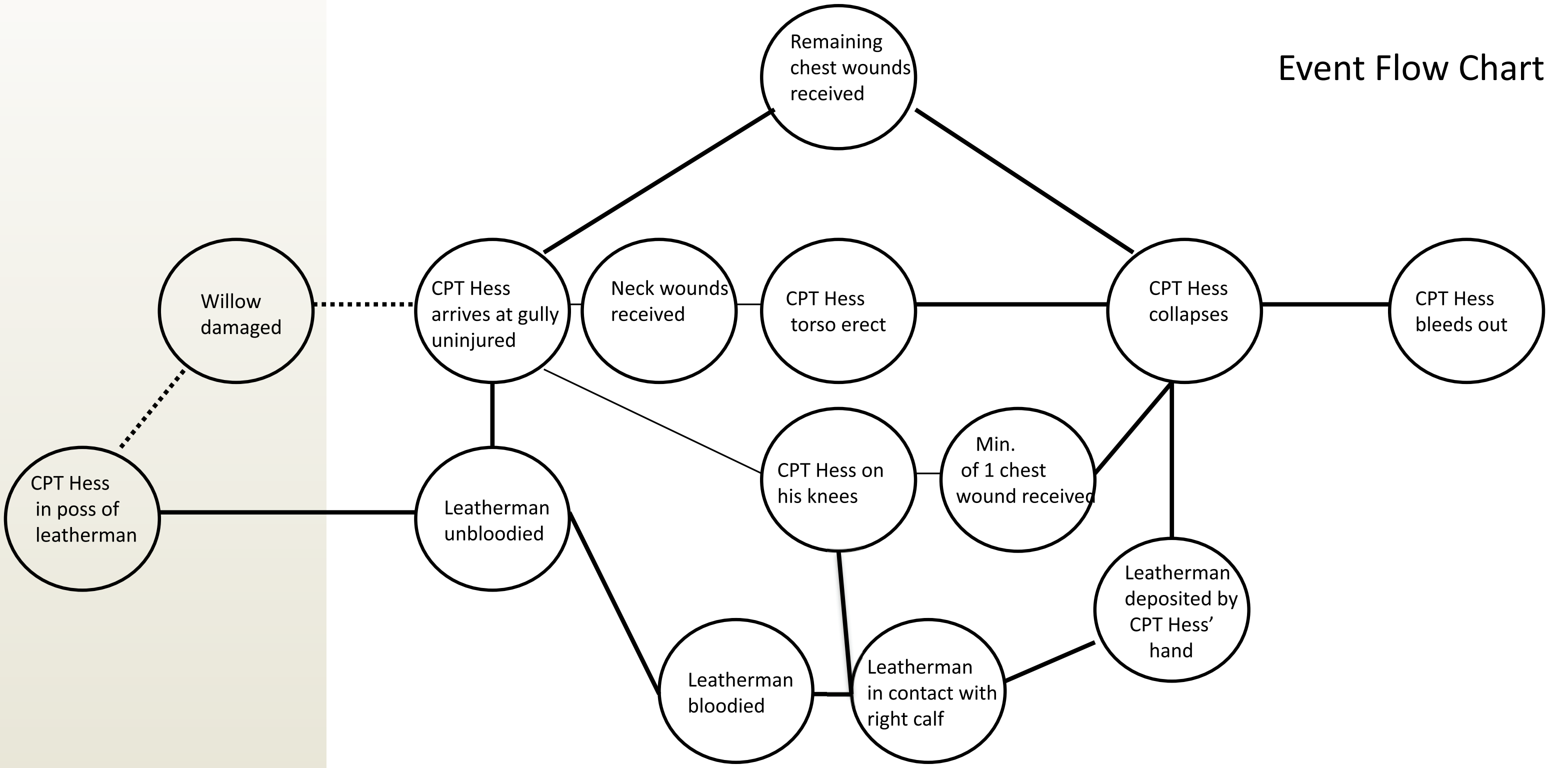

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Figure 1: The Event Analysis Flow Chart is a graphical representation of the convoluted actions defined by the analysis. Actions are represented left to right in sequential order. Known sequential relationships are shown with the connecting lines. The final flow chart is effectively the sum total of the analysis, defining what happened and in what order it happened.

or artifact of interest, then such information is utilized as data.

MES identifies the Event Blocks through a process known as change tracking method (CTM). A specific actor is tracked and changes in condition, position etc. are documented. As defined by Benner "CTM requires concrete observations of, or data from, any person, document or animate or inanimate source, including the description of things remaining after the occurrence." [16]

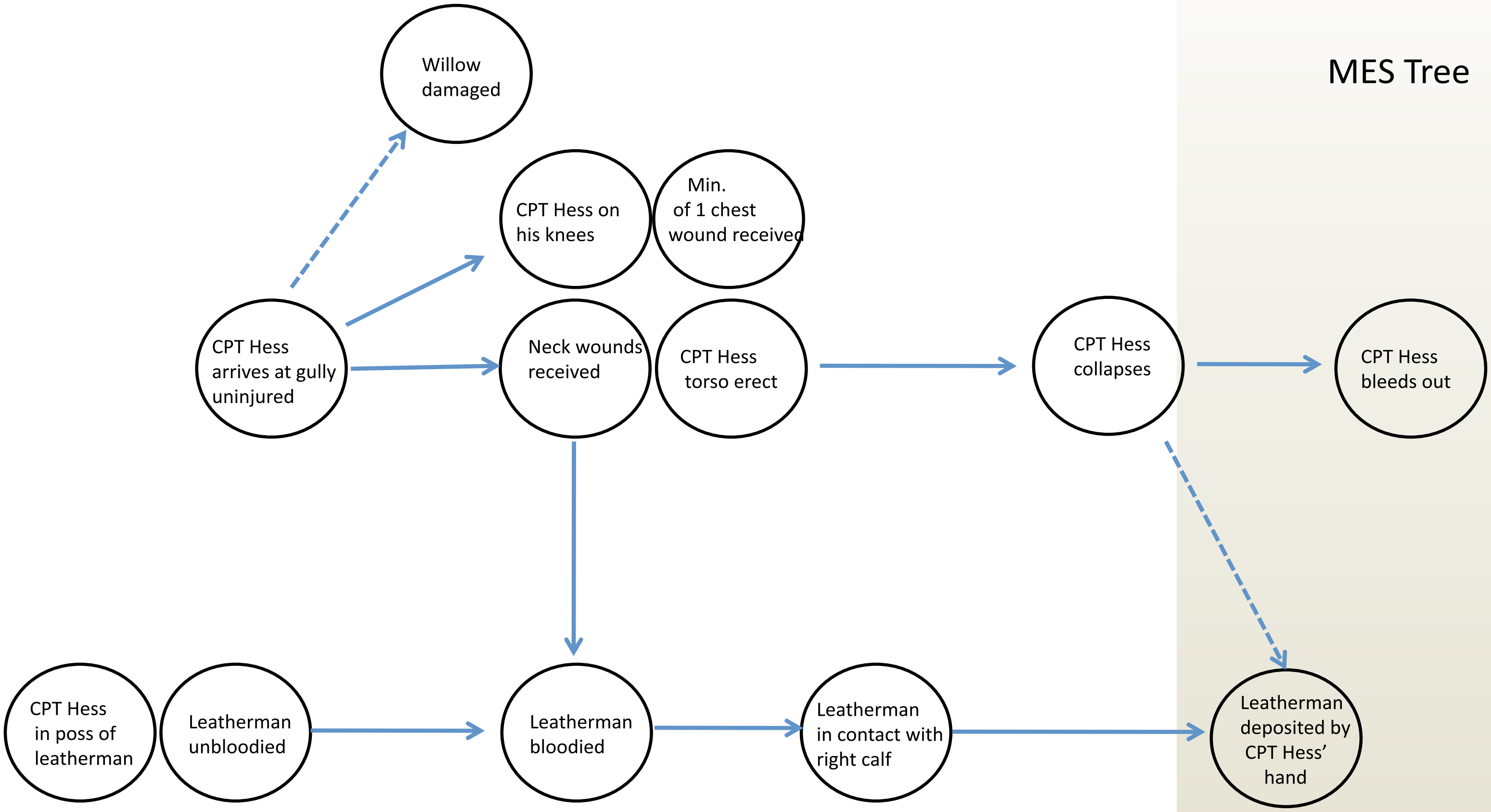
The only difference between data sources used in the two techniques lies in testimonial evidence. EA is based on the recognition that people can lie, fill in blanks in their memory or simply perceive things incorrectly when involved in criminal events. This concern was first articulated in 1898, when Hans Gross commented that if investigator's heap testimony upon testimony, they will "almost always be led astray and found wandering from the goal (the truth) [17]. MES on the other hand is designed around system failures that routinely involve human beings. To functionally understand why a system failed (e.g. a plane crash or industrial plant explosion) the analyst must consider how the various people involved acted or failed to act based on their perceptions of what was occurring around them. For that reason testimonial evidence is a necessary element of the MES process. Beyond this distinction both systems use the same basic data sources.

EA and MES Output

The most significant work product resulting from either Event Analysis or Multilinear Events Sequencing is the graphical flow chart each technique produces. These work products allow the viewer to more effectively grasp the nature and sequence of the actions involved. It also allows for more effective logic testing of this order and helps the analyst recognize where gaps exist in the analysis.

In EA the analyst produces a flow chart of event segments. The event segments are sequentially ordered and depicted based on any known relationships. Figure 1 is an example of an Event Analysis Flowchart.

MES Tree



▲ **Figure 2: The Multilinear Events Sequencing Tree is also a graphical representation of the analysis in a slightly different format. Each tier tracks a particular actor, with actions listed in appropriate sequential order left to right in the tier. Each tier's actions are oriented sequentially with other tiers. This tier format, although effective, is not conducive to crime scene analysis. The lack of specific sequence and causal information always produces a convoluted representation. In an MES tree the connecting arrows between tiers represent causal connections, not sequence. These lines may have to cross several tiers to show the causal connection.**

The actions are generally ordered in a left to right orientation and arranged across the page based on both causal and temporal associations.

In MES the analyst produces a flow chart called the MES Tree or Matrix. Event blocks are arranged in tiers within this flow chart. Each tier, in effect tracks a particular actor. All of the event blocks associated with that actor are arranged in linear orientation, left to right and in sequential order. The MES tree then depicts causal relationships between different actors (different tiers) by interjecting arrows from the appropriate location in one tier to some point in another tier. See Figure 2.

These graphical work products are significant in accomplishing both techniques. The graphical output is not just an end product; it is an integral part of each analysis. Significant logical reasoning as well as a search for data to support the sequential order presented in the flow chart are necessary to produce these charts. Each flow chart is analyzed and scrutinized from its inception for logical errors by the analyst.

Practical Utilization of the Resulting Work Product

Using either EA or MES, all effort in analyzing these unique incidents is done to define objective statements of what happened and in what order they happened. Neither technique has the ability to provide a Point A through Point Z description of the incident in question. In fact, it is difficult to imagine a scenario where there would ever be sufficient data available to produce such an end product. There will always be claims of actions or activity, for which the physical evidence available will neither corroborate nor refute that the action occurred. Nevertheless, what these techniques produce are objective statements of what actions did happen as well as the recognition of what actions could not have happened. Any claims made by anyone about gaps in this information can be considered as distinct hypotheses. These claims become theories that are compared to the analysis. If the theory matches up to the analysis, that theory is possible and remains a viable explanation. If the theory contradicts the analysis, it is refuted. As required of all scientific effort, once refuted a theory must either be revised to resolve the contradiction or abandoned as a viable explanation.

Summary

Crime scene analysts are asked to evaluate both the scene and the debris of alleged crimes in an effort to describe what happened and in what order it happened. Whatever method they use to pursue this purpose must be objective, at least if their effort is to have value to and meet the scientific standards expected by the judicial system. Event Analysis is a specific crime scene analysis technique designed around this objective. Event Analysis is based on themes found in the long history of crime scene analysis and criminal investigations, but it also mirrors a technique that developed in the framework of modern scientific scrutiny. This newer technique, Multilinear Events Sequencing, is an established process utilized by engineers, scientists, and accident investigators to explain unique events in their individual areas of study.

To effectively survive a Daubert or Frye style challenge in court, the crime scene analyst must describe the underlying theory, principles and methodology associated with Event Analysis. This technique must stand on its own merit. But when the question is posed: To what degree has Event Analysis technique and theory been generally accepted by the scientific community? The analyst can respond in a strong and very specific fashion. These two techniques, Event Analysis and Multilinear Events Sequencing, match each other in process and form from inception to end. The only differences noted between these systems of analysis are minor. Each produces a flow chart made up of the same basic building blocks presented in a sequential format, but one chooses to do so linearly while the other does not. The second difference lies in the data used in forming the conclusions. EA reduces the analyst's reliance on subjective testimonial evidence, whereas MES must incorporate such information. Beyond these differences they are effectively one and the same technique.

If considered scientific in one discipline, a technique cannot logically become unscientific when used in another. Any claim that Event Analysis is unscientific, is in fact a statement that the MES technique employed by scientists, structural engineers and failure analysts is also unscientific. Granted some lawyer will eventually have the gall to make this preposterous claim, but if a judge gives credence to and accepts it, then simply put science itself has no chance and that community has bigger things to worry about than the guilt or innocence of one person.

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