

1

What Is Forensic Systems Engineering?

CHAPTER MENU

- 1.1 Systems and Systems Engineering, 1
- 1.2 Forensic Systems Engineering, 2
- References, 4

Forensic systems engineering can be defined as the preparation of systems engineering data for trial. This snapshot raises more questions than it answers because neither “systems” nor “systems engineering” enjoy general agreement on what they mean. *Forensics* is well defined and refers to the application of scientific knowledge to legal problems. Conversely, *systems engineering* has no generally accepted definition and each discipline holds its own parochial notion of it. When I entered the systems engineering program at the University of Virginia, only one other university in the United States offered a degree in the field.

In the computer world the term refers to the design and implementation of hardware and software assemblies. In the Department of Defense, it refers to large human machine structures. Systems theory itself is substance neutral and can be applied with equal vigor to computers, machines of war, video assemblies, banks, institutions, dams, churches, governments, ports, and logistics—any dynamic activity with a determined goal. So let us begin with the meaning of a *system*.

1.1 Systems and Systems Engineering

The Kalman et al. (1969) definition of a system, shown in the Preface, is repeated here for facility: a dynamical process consisting of a set of admissible inputs, a set of single-valued outputs, all possible states, and a state transition function. Two of these criteria are particularly significant in forensics. Admissible inputs are essential to the proper operation of a system and will be

important characteristics in forensic investigation. An admissible input is one for which the system was designed. The output of a system subject to inadmissible inputs is not predictable and may be nonconforming to requirements.

In practical operation, the second Kalman criterion of a state transition function refers to that mechanism by which the system changes its state. This mechanism must be controllable and observable. An implementation or change to a system that frustrates these qualifications implies a nonconforming system. In this book, then, I define a “system” as a dynamical process consisting of a set of integrated elements, admissible inputs, and controllable states that act in synergy to achieve the system purpose and goal.

At the University of Virginia’s School of Engineering and Applied Science, Professor John E. Gibson (2007) defined systems engineering as “operations research plus a policy component,” the latter adding the question of “why?” to the engineering “how?” Operations research (OR) concerns the conduct and coordination of operations or activities within an organization (Hillier & Lieberman, 1990). The type or nature of the organization is immaterial and operations research can also be applied to business, industry, the military, civil government, hospitals, and so on. As a forensic examination will compare what is to what should be, then contracts too, may be of concern.

In this book, then, we define *systems engineering* as the creative application of mathematics and science in the design, development, and analysis of processes, operations, and policies to achieve system objectives.

1.2 Forensic Systems Engineering

Forensic analysis is the application of scientific principles to the investigation of materials, products, structures, or components that fail or do not function as intended. Situations are investigated after the fact to establish what occurred based on collected evidence. Forensic analysis also involves testimony concerning these investigations before a court of law or other judicial forum (Webster, 2008).

If a failing material, product, structure, or component is a subset of a system, then the cause of failure may be the system itself, and if so, failure may be systemic. Therefore, the system itself is properly within the purview of forensic investigation. This idea is particularly important when the failed unit is mass produced and sold widely. An investigation of a failure in Baltimore will say nothing about a similar failure in Miami or elsewhere; there may be systemic failure and only a system level investigation will reveal it. If so, then the productive system, too, requires forensic investigation because only a system-level approach can determine the root cause.

Therefore, I define *forensic systems engineering* as the investigation of systems or processes that have failed to achieve their intended purpose, thereby

causing personal injury, damage to property, or failure to achieve contracted requirements. The basis of the investigation will be the fit of the system in litigation to contract requirements according to systems engineering criteria. Established systems theory and system analytical tools are used extensively in the investigation. Such tools include probability models, linear and nonlinear programming, queuing theory, Monte Carlo simulation, decision theory, mathematical systems theory, and statistical methods. The purpose of forensic systems analysis is to identify dysfunctional processes, to determine root causes of process failure, and to assist the court in determining whether harm or a breach of contract has occurred.

Forensic systems engineering includes all of the components of engineering: design, development, operations and analysis, and synthesis. Forensic systems analysts will aid counsel in designing and developing case strategy, based on preliminary overview of findings. In this pursuit, they will use formal scientific methods in analysis of evidence.

All products are manufactured and all services organized through business processes that are integrated so as to contribute to a symbiotic or synergistic goal. In this way the processes compose an operational *system* and systems theory applies. The consequences of system failure can be dealt with by a new legal concept called *process liability*.

For ease of reference, I repeat from the Preface that in this book the term *operations* refers to both production and service. Operations can be managed in an orderly fashion with a systematic approach using well-recognized good business practices, which we shall call a management system. A company with a formal management system has the best opportunity to consistently meet or exceed customer expectations in the goodness of its products and services.

A management system should be synergistic—the parts work together effectively to achieve the system goal. All the productive and supportive activities in the company are integrated and coordinated to achieve corporate goals. All productive processes should be organized in the natural flow of things and supported with necessary resources. This type of structure is called the process approach and is suitable to the newer standards of performance. Also, the performance of the management system is continually measured for effectiveness and efficiency, with structures for improving performance.

The forensic systems analyst should understand the relationship between system and standard. Simply put, a standard is a model—pure form. It does nothing, but it enables things to be done well. Performance standards offer consistency, efficiency, and adequacy. The system is the implementation of the standard and provides the substance. Properly implemented, the system will work well and get things done to the satisfaction of the customer, performer, and shareholder.

An investigation is akin to an audit in that it compares the descriptive system to the normative—what it is to what it should be. As discussed in the Preface,

the ISO 9000 (ANSI/ISO/ASQ, 2005) Quality Management System is chosen as the standard model of this book to be used in such comparisons. However, in the absence of a contract requirement for a specific standard, any equally capable standard may do, even a locally developed one. The issue in litigation is whether the performer is prudent in standards of care and due diligence.

In 1970, attorney Leonard A. Miller presented a paper in the *New England Law Review* that introduced the concept of process liability and traced legal precedents that justified its use. With permission of Mr. Miller, several paragraphs are extracted from his paper and inserted into Chapter 6 because of their pertinence to forensic investigation. Although referring to pollution control, his arguments for process liability clearly apply as a consequence of non-conforming or dysfunctional processes.

Businesses differ in how they refer to their core entities: systems, processes, cost centers, activities, and business units, to name a few. In this book, these terms may be used interchangeably to accommodate the various backgrounds of readers. But whichever terms are used, their dynamic property does not change. Whatever it is called, a system is designed to use states and feedback loops to change admissible inputs into specified outputs. It consists of the resources, inputs, outputs, and feedback mechanisms necessary to make the process work correctly and consistently. The conditions required by every system are (i) the input must be admissible—appropriate to the system design; (ii) the states of the system are established by proper set up; (iii) the feedback loop provides the capability to compare what is to what should be; (iv) and the outputs are in agreement with system objectives. In litigation, each of these conditions can be challenged and may be the focus of forensic investigation.

In sum, a performer offers to provide a product or service to a customer. A contract is drawn up listing customer requirements and the intended use of the product or service. There may also be specifications on the performance itself, such as constraints of cost and time, or the requirement to perform in a certain way, say in accordance with given industrial or international standards. In the event of customer disappointment, a forensic investigation may be called for in which it becomes apparent that a process or operation may be a contributing factor in an adverse outcome. Both plaintiff and defense attorneys may well consider forensic system engineering in their strategies.

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