LIFE CYCLES FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION

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Contents

Summary

Sustainable development is a goal that is based in part on system level concepts of communication, teamwork, and leadership, which are facilitated by the introduction of common structure into the engineering process. Drucker and Sage have provided robust structural models that lead to an understanding of engineering and engineering organizations in terms of three interrelated life cycles: the research, development, test, and evaluation cycle; the acquisition cycle; and the planning and marketing cycle. Each life cycle is a system that demands products and, in turn, contributes products to the other systems in the organization. Products for the acquisition cycle include options and alternatives for the management of development or procurement activities; for the establishment or improvement of acquisition processes, such as the definition of requirements, design methods, or testing strategy; and for product level decisions, including the best use of materials, comparisons of design options, and considerations of delivery, packaging, maintenance, and operation. Products for the planning and marketing cycle include assessments of market conditions and options, including tradeoff studies and prototyping, for response in many areas. In the area of management, studies may focus on the practices of competitors or innovations within the organization. Process studies may address distribution channels, communications, and response to competitive practices. A focus at the product level includes test marketing and other forms of proactive, as well as reactive, market analysis. In the article *Life Cycles for System Acquisition* we focus on the acquisition cycle and its interfaces to the other two cycles.

1. Introduction

Our understanding of system life cycles is based on our understanding of systems. A system is a purposeful, structured relationship among parts such that the relationship brings forth properties that are not manifested by the same parts outside the system. Systems may be natural or synthetic, or they may be a hybrid of natural and synthetic subsystems.

The term “life cycle” is of relatively new origin. References in the 1950s to life cycle costs denoted the operational costs or the cost of ownership of a system, exclusive of the development cost. The scope of the term “life cycle” has since evolved to include all phases of the life of the system, beginning with the system concept and continuing through system decommissioning and disposal. As used in the systems engineering community and in this paper, the term is a synonym for “process model.” Because of widespread interest in the engineering community on product quality and process repeatability, there has been a great deal of attention both to the structure and the function of life cycles and, to a lesser degree, to their purpose. Many authors prefer other names for the acquisition process model, such as the “project cycle,” the “procurement process,” the “production cycle,” or the “implementation process.”
This is the first of three papers concerned with system life cycles. For many reasons, a number of which relate to the systems engineering organization, it is beneficial to regard a process model as an ordered collection of developmental phases that, when taken together, yield a desired result. We refer to this ordered collection of phases as a life cycle. Using a basic enterprise model developed by Sage, a process will be of one of three types: research, development, test, and evaluation (RDT&E); system acquisition or production; or planning and marketing. It is possible and desirable to identify life cycles for each of the three basic classes of process. Thus, we may speak of an RDT&E life cycle, a system production or system acquisition life cycle, and a planning and marketing life cycle.

A life cycle is a model that we use to guide the organization of engineering projects, programs, or enterprises, or with which we understand or interpret engineering events. We understand engineering in the light of the life cycle model, and we understand our life cycle model in the light of the engineering work that we actually do. The more we experience, the more we understand the model. Although the model provides a useful framework, it is not a recipe. It is simply a device by which we catalogue our experience, transmit our learning, and acknowledge that there is a process at work. This process is called “engineering a system” and differs from systems engineering only in the role that is played by the engineer in the organization. All engineers, including systems engineers, are engineers of systems. Systems engineers are looking, appropriately, at the requirements—the design decisions throughout the process, with particular emphasis on emergent properties of the design.

Life cycles are tools of management that guide the organization of enterprise activities around a purpose; and their use may be descriptive, prescriptive, and normative. Our purpose is to provide a model for the engineering of products that are responsive to the needs of societies, economies, and environments in which our systems are placed. The overall goal of sustainable development includes sub-goals of communication, teamwork, and leadership in the development of systems. The sub-goals are difficult to reach in the absence of common process models for the engineering of our systems. In our study of system engineering life cycles, we recognize life cycle models for their simplicity in describing processes and also for their prescriptive utility in organizing the enterprise. When an organization undertakes an enterprise, management creates structure according to its goals. Organizations create structure with processes according to some partition of the enterprise. Moreover, life cycles provide a normative model of success—a reference model designed to reduce fear of failure. Expectation brings about what is expected; accordingly, as life cycles are designed to succeed, they mitigate risk. Drucker provides a basis for the classification of organizational activities according to their contribution to the organization. He defines four major classes:

- result producing activities
- support activities
- hygiene and housekeeping activities
- top management activity.

Of Drucker's four classes, only result-producing activities have nontrivial life cycles. The other three types are on-going, organic elements of the organization, whose valuable activities are required, but whose value cannot be measured directly. Drucker also identifies three subclasses of result-producing activities:

- information activities that feed the corporate appetite for innovation,
- activities that do not directly generate revenue but are still fundamentally related to the results of the enterprise, and
- activities that directly generate revenue.

Each one of Drucker's subclasses corresponds to one of three basic systems engineering process types identified by Sage, each with its own life cycle that we will examine in detail. In turn we will discuss:

- the RDT&E life cycle,
- the acquisition or production life cycle, and
- the planning and marketing life cycle.

With respect to each life cycle type, it is necessary to formulate, analyze, and interpret (synthesize) a response to the market. The market may be external or internal to the organization.

Sage represents a generic system life cycle as a three-phase model: definition–development–deployment (D–D–D). Each phase may be further examined using the formulate, analyze, and interpret (FAI) construct to categorize the activities contained in that phase. Activities and products may be organized as a matrix and represented as suggested by Figure 1.

	Formulate	Analyze	Interpret
Definition			
Development			
Deployment			

Figure 1. Activities and products organized as a matrix

The D–D–D model is itself a variation of FAI, and both may be applied recursively. Each phase may be considered to be a stand-alone process, each with inputs and outputs. Each phase may then be further analyzed using a recursive application of the D–D–D or the FAI model. System definition is essentially a formulation (F) activity during which system requirements are discovered, classified, analyzed, and articulated as specifications. Development is an analysis (A) activity in which requirements and alternatives for their realization, are considered, analyzed, evaluated, and developed. Deployment is an interpretation (I) step, in that the results of the development phase are integrated to construct an operational system.

A generic selection function performed by each of Sage's three basic systems engineering life cycles may be illustrated by three filters through which a product concept must pass to be deployed successfully by an organization (see Figure 2). Each successive filter "downselects" or reduces the size of the universe of possibilities, based on factors both internal and external to the organization.

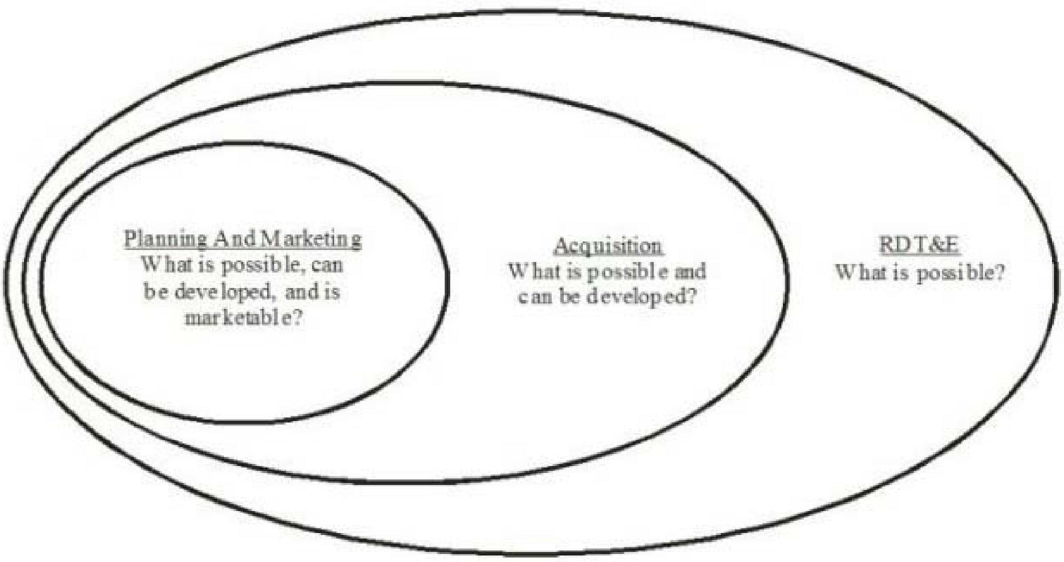

Figure 2. Three basic systems engineering life cycle filters

In the RDT&E cycle, potential success in the deployment of new ideas is evaluated in the light of current and evolving technology, constrained only by the goals of the organization. The acquisition cycle narrows the range of possibilities by subjecting the possibilities visible to the RDT&E organization to the capabilities of the production organization. Finally, from the viewpoint of the planning and marketing cycle, the direction of focus is outward to the external market. We may note that these three successive filters have, in terms of their direction and focus, the same characteristics as the three parts of our FAI framework:

- "formulate" looks at new possibilities with a goal orientation;
- "analyze" looks inside the enterprise and considers the development of the product in the light of available resources; and
- "interpret" looks outward, answering patterns of need from the market in terms

of possible, producible, and marketable alternatives based on organizational capabilities.

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Biographical Sketch

F.G. Patterson Jr. received a B.A. degree from Rhodes College, two M.S. degrees from the University of Memphis, a Sc.M. degree from Brown University, and a Ph.D. degree from George Mason University: the most recent in 1996. He has been a faculty member at several universities, in departments of computer science and systems engineering; has worked as a systems engineer in the aerospace industry, and has worked for the National Aeronautics and Space Administration (NASA). His experience includes extensive assignments on large complex systems undertaken by the Federal Aviation Administration and by NASA. His interests include systems engineering and systems management, especially the areas of process improvement, software reuse, and new paradigms for rapid system design.