VALUE SYSTEM DESIGN FOR SUSTAINABILITY

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Contents

Summary

The purpose of this article is to show how and why value system design is an integral part of the best problem-solving procedure of our day, which is systems methodology, originally derived from systems engineering, operations research and management science. It is integral because no real system can be designed nor a present one saved without a comprehensive statement of what is needed, and the requirements for it to become a harmonious fit with its intended environment, a statement most accurately defined as a value system design. With our global system having existing proposals for its modification, if not re-design, we need standards to inspect existing or implied value systems for these changes to ascertain if they are good in any meaningful sense. If they fail to pass inspection, it does not follow that the proposals will fail. It only means that the probability of failure or of certain unwanted consequences is higher if the methodology is flawed.

When advancing new global proposals, the initiators need to be keenly aware of the principles for designing good value systems, especially when an entire life cycle is anticipated. Compared to the physical and biological sciences, these principles are not provable, nor do they form an irrefutable whole. However, in the light of experience, publications, and of successful operating systems during the last 45 years, one can say that the philosophy and techniques now available are very useful while the approaches still evolve.

1. Introduction

This encyclopedia aims to provide knowledge that can help in designing and maintaining a life support system for the world. At other times and places such a grandiose goal would invite derision. Now, with the backing of the United Nations, a large representative sampling of leaders from many nations and many branches of science and engineering have coalesced in several venues to declare that some current trends threaten to endanger the continuance of life on earth. Some activists see certain trends as crises, and these trends have motivated the EOLSS to provide the knowledge for remedial action.

The EOLSS has presented on its internet home page a definition of a "life support system" that is intended to add clarity and specificity to the mission given above, as follows:

A life support system is any natural or human-engineered system that furthers the life of the biosphere in a sustainable fashion. The fundamental attribute of life support systems is that together they provide all of the sustainable needs required for continuance of life. These needs go far beyond biological requirements. Thus life support systems encompass natural environmental systems as well as ancillary social systems required to foster social harmony, safety, nutrition, medical care, economic standards, and development of new technology. The common thread of these systems is that they operate in partnership with the conservation of global natural resources.

The EOLSS provides a focus in listing its content headings, which are: 1. Global Sustainable Development, 2. Water, 3. Energy, 4. The Environment, 5. Food and Agriculture, and 6. The Knowledge Foundations.

Together these statements invite many questions relating to the purposes of this article, which are:

1. How to relate value system design to the whole of which it is a part, namely systems methodology. 2. How to inspect a value system design for any project to see if it is good in any meaningful sense, and 3. How to design a value system design and test its quality for the project in question.

Here are a few questions that cannot be answered in this article, but for which systems methodology, the best problem-solving procedure of our day, increases the probability of correct answers:

What is the time frame for sustainability? Ten years, a century, to the demise of our sun?

What variables among the six "areas" of the encyclopedia are intended to be sustained, or controlled, and within what limits or rates?

What is meant by "development": increased income per capita, level of educational attainment, gross world product, number of people owning voice recognition software, etc?

Which human needs are to be promoted and/or sustained? Is the focus merely on physiological needs like safety, or do they also include higher level needs, such as freedom?

Are some "sustainability" actions now underway misguided in the light of the best methodology and technology?

2. Relations between Systems Methodology and Fractal Geometry

The connection between fractals and systems engineering starts by defining systems methodology (SM) as follows:

SM is an efficient, multiphase, multilevel, multiparadigmatic, creative process for finding, defining and solving complex problems by using well-defined teams. It satisfies needs and seeks logical, factual and value truths by matching a wanted system and its parts to its full environment over its entire life cycle.

This definition implies two hierarchies, the first being temporally ordered by time phases, and the second spacially ordered by physical systems: value system (metasystem), physical system, subsystem, modules, components & materials. A fractal requires a minimum of one hierarchy, but here we have two. Table 1 provides a comprehensive morphology of SM.

♦ The *time dimension* scales the sequence of events from conception to death of the system. Major decision milestones segment this life cycle; the intervals between define about seven phases. In order of decreasing scope, they are typically program (portfolio) planning, project planning, system development, production (or construction), distribution (or phase in), operation, and retirement (or phase out).
♦ The *human dimension* accounts for human needs like freedom, personalities, culture, management styles, attitudes, biases and pathologies of individuals and groups as they affect choice of facts, values, models, levels of risk, and all environmental factors of the overall process.
♦ The *knowledge dimension* is a unique mix of facts, values, models and techniques, usually from conventional fields such as engineering, economics, architecture, medicine and law, to plan, develop, design, produce and use the system within its life cycle.
♦ The *logic dimension* defines a generalized human group problem solving process of about seven unit elements. There is no temporal or logical priority among them, but each must be performed before completing a phase. These elements are replicated for each phase, and also at lower levels for subsystems, modules, components and materials within each phase, as controlled by hierarchical logic. The structure of these elements forms a "fractal unit".

Table 1: Four Dimensional Morphology of Systems Methodology

There are three properties that define a fractal: (1) A self-similar property shown by some "object" whose parts resemble the whole, and so on down some hierarchical scale. (2) The sizes of the parts decrease by a constant amount. (3) There is a randomness property, wherein some feature of the objects varies about some central tendency. These properties may be seen in a huge variety of natural systems, for instance a common spleenwort fern. This fern has an overall shape, repeated for each leaf but at a smaller scale. The branches are distributed about an average spacing along the stem.

The time dimension is the one just referred to as being a temporally ordered hierarchy.

The logic dimension contains the elements of a generalized problem solving process, replete with feedback and an arbitrary number of iterations among the associated (at least) five feedback loops (c.f. Figure 3).

The logic dimension is non-hierarchical; the elements of it have no temporal or logical priority and are independent of any specific domain of knowledge. You should visualize a matrix as one plane in the spatial hierarchy, that is, one plane at the system level, another plane at the subsystem level, etc. The elements of the fractal unit need to be defined with more precision than given on the matrix itself, as may be seen in Table 2.

Problem Definition, including environmental forecasting and impact assessment, in principle must be done over the entire system life cycle. Essential activities include isolating, quantifying, and clarifying the need that creates the problem, and describing that set of environmental factors which define the system and its environment. This descriptive scenario models the operational situation, user requirements, economic policy, legal considerations, and possible system inputs and outputs.

Value system design, or metasystem design, or normative scenario production, means to select the set of objectives and goals that will guide the search for alternatives, imply the types of analyses required of the alternatives, and provide the multidimensional decision criterion for selecting the most appropriate ("optimum") system.

Systems synthesis, or collecting, searching for, or inventing a set of ideas, alternatives, or options. Each alternative must be worked out in enough detail to permit its subsequent evaluation with respect to the objectives, and to permit an application of the multidimensional decision criterion to decide its relative merits for proceeding into the next phase.

Systems analysis means deducing those sets of consequences specified as relevant by the value system. These deductions may relate to quality, market, reliability, cost, effectiveness, quality of life, freedom, privacy, etc.

"Optimization" of the alternatives, or proportioning the system variables to meet the objectives, entails interaction of the first four steps, often by using a model for selected system attributes which may be useful in the proportioning.

Decision making involves evaluating the consequences of the alternatives developed in systems analysis relative to the objectives, and incorporating these evaluations into the decision criterion so that all alternatives can be compared relative to the criterion, to the end that one or more alternatives can be selected for advancing to the next phase.

Planning for action to implement the next phase includes communicating the results of the process to this point, scheduling subsequent efforts, allocating resources to carry out the work, assigning priorities for subsequent action, setting up a management control system consisting of performance criteria and feedback methods. If we were not modeling a multi-phase system, this step for starting and controlling action would be final. In this model however, implementation refers to the next phase.

Table 2: Elements in the Logic of Systems Methodology Comprising the "Fractal Unit"

These elements can be interpreted as components of one dimension, and the time dimension can be portrayed to obtain a two-dimensional matrix suggesting their orthogonality. All elements must be performed in each of the phases for any project holistic enough to range over the entire gamut of the life cycle.

Such a matrix may be used to portray each level in the space dimension, so that we may visualize a three-dimensional cube. Each cell of the cube contains a problem-solving process defined by the elements of the logic dimension above, which can properly be called a fractal unit.

If the fractal units successfully perform their work in each cell, then the overall project will converge at the project conclusion with a sustainable system embedded in its anticipated environment. A suggestive model for this situation is that of a cornucopia showing a converging spiral of the time dimension, iteration of the fractal units, and wall thickness representing the layers of the spatial dimension.

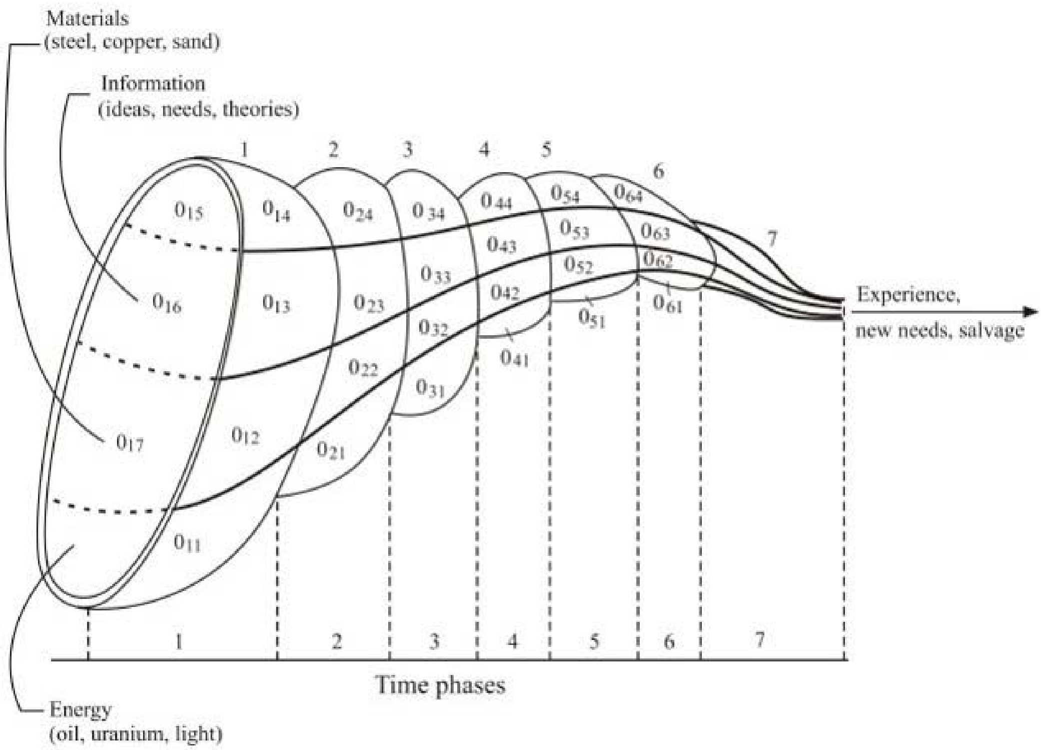

Figure 1: The Cornucopia Model of Systems Methodology Showing Iteration, Convergence and Fractal Structure.

From it you can see that both the time and the space hierarchies show scale reduction as required of a fractal. As in any fractal, if convergence fails to obtain, the entire system, or parts of it, may "blow up" or become unstable.

A major proposition of systems methodology is that this fractal structure is essentially the same in any component of the knowledge dimension. The same process, using each and every one of the fractal elements, is the same in every applied science, whether social or physical. By perceiving that pure scientists face the same problems of setting objectives in broad areas of learning generally thought to be outside their interests, pure scientists also exercise the basic fractal unit.

3. A Close Look at Value System Design

Whenever we design a system, we really design three of them. The first is the value system (VS), a metasystem that is a verbal description of the wanted system. The second is the physical or concrete system built in response to, and implied as a possible embodiment of, the value system. It includes both hardware and software, but a concrete system need not necessarily have any hardware. The third is the logistic system, containing all subsystems needed to install, maintain, operate and use the concrete system, including phasing in and phasing out the new system to control environmental dislocations while reaping the desired benefits. "Sustainable" systems may not refer literally to hardware or software systems subject to design as known in industrial R & D. They may refer to selected features and attributes of systems found in nature subject to modeling in such a way that the selected features show some dislocations, imbalances or pathologies perceived as threats to certain peoples, countries, regions or even globally. No matter, the approaches to all kinds of systems are of a piece to be considered jointly.

The most fundamental and important of these three systems is the VS, because without it no system, or the wrong system, will be designed. It is also the most difficult to teach, to learn and to practice. Poor or faulty value system design (VSD) is the most frequent cause of concrete and logistic system failures. Designers produce systems every day for markets that do not exist.

They design artifacts to solve questions that no one asked. They often design systems that are not feasible socially, economically, legally, and even physically. Sometimes sustainable systems are proposed to be "fixed" before sufficient scientific knowledge can endorse the fixes, or even before the global system is on an unsustainable trajectory. We need standards to guide efficient VSD just as today we have standards for designing hardware systems of most kinds.

It is time to offer a more precise definition of value system design (Table 3). The first paragraph in it relates VSD to the other elements in the logic of systems engineering expanded later. The second two paragraphs offer dependent concepts of a value system.

<u>Value System Design</u>, metasystem design, or normative scenario production, refers to a somewhat specialized fractal unit of systems methodology for choosing a set of objectives and goals (the values) which will guide the search for alternatives, imply the types of analyses required to be performed to evaluate the alternatives, and provides the decision criterion (or criteria), for selecting the most appropriate ("optimum") system.

<u>A Metasystem</u>, in this instance a value system, dominates the physical or concrete system to be designed, in the sense that at least its outlines (general structure, logic and sequence) must be established before a physical system can be designed, and in the sense that its elements must, on the average, precede the physical system design.

A <u>Normative Scenario</u> is a central element of any formal plan for a major project, and is a narrative statement of what is, or ought to be wanted, i.e., the value system. It contrasts with a <u>descriptive scenario</u>, which describes the present environment and projects it over the anticipated life cycle, and is the major output of the problem definition element of SE. It further contrasts with a transition scenario, which describes how to get from now to then, i.e. how to satisfy the normative scenario with some new system set in place. Any good plan will have these three scenarios, all within well-defined time horizons and intermediate milestones.

Table 3: Value System Design: Key Definitions

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Biographical Sketch

The author of the paper in this encyclopedia on "Value System Design", recently deceased, was a pioneer in developing systems engineering, in which value system design is a major element. This is reflected in the books and journal articles cited in the paper. He wrote the first definitive text on systems engineering (1962), which resulted from research and teaching experience begun in the early 1950s to systematize and extend the practice at Bell Telephone Laboratories. He continued to broaden and deepen the subject through experience as an executive at two corporations, by heading his own consulting corporation, and by further teaching and research at the University of Pennsylvania. One result was a second major book (1989) on "Metasystems Methodology" which provided a new synthesis and unification of systems-methodology. His tertiary education began at Princeton University with a degree in physics and electrical engineering. Three years of graduate work was completed at BTL in telecommunications technology, and post-graduate study continued at Johns Hopkins, Newark College of Engineering and MIT.

Hall had a lifelong interest in sustainable systems, from being raised on a farm, owning and operating two farms. This merged with his experience in information technology in his research, inventions and patenting of "Autofarm", which demonstrates how to increase farm productivity ten times, while reducing energy and materials requirements and pollution. This system demonstrates a systems approach to all functions of a single farm but is also applicable to a set of farms too small to justify the large-scale mechanization used in the U.S. Agriculture is the most important human activity, and far more efficient practices must be found. It is clear that computing and telecommunications technology, as taught in the patent applied to agriculture, will be assimilated and used.