Reducing and Managing Complexity by Changing the Boundaries of the System

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Abstract

The world is facing the problem of managing complex systems, yet no practical solution is in sight. This paper suggests that the solution to the problems of complexity will only be found by using "out-of-the-box" thinking to change the paradigm and proposes a number of hypotheses, to help initiate that thinking process. The paper considers that the various definitions of the term 'system' are problem statements, and hypothesizes that the problem may be solved, not by tackling complexity, but by bypassing it by changing the way it is viewed. The paper also provides a new definition of the word 'system' that seems to apply to all five layers of system engineering (Hitchins,2003).

Introduction

The world has been turning to systems engineering to help manage the problems of complexity for at least 28 years (Shinner,1976) yet no practical solution is in sight. By recognising that "excessive complexity is a symptom of an underlying problem within the foundation of the current paradigm" (Kasser,1996), this paper suggests that the solution to the problems of complexity will only be found by using "out-of-the-box" thinking to change the paradigm and proposes a number of hypotheses, to help initiate that thinking process.

The paper starts by pointing out that the definitions of the word "system" are numerous and different. This paper then hypothesises that these many definitions are formulations of problem statements and provides a new definition of the term from an object-oriented perspective. The paper continues with a discussion of reasons for, and implications of, the new definition and proposes that Complexity can be dealt with, and managed by redrawing the internal and external system boundaries in the context of a Simplicity paradigm. The paper shares some perspectives on the consequences of the new definition and the insights it provides. A case study of a project success attributed to the Simplicity paradigm is discussed. The paper concludes with yet another definition of systems engineering, however this one does seem to cover all five layers of systems engineering (Hitchins,2003) at all points within the two dimensional space defined by (Kasser and Massie,2001).

The various definitions of the word "system"

The word "system" means different things to different people. For example, (Webster,2004) contains 51 different entries for the word "system". Consider the following representative sample of definitions of the term taken from various sources from the last forty years:

- An array of components designed to accomplish a particular objective according to a plan (Johnson, Kast and Rosenzweig,1963).
- A set of concepts and/or elements used to satisfy a need or requirement (Miles,1973).
- An assemblage or combination of components or parts forming a complex or unitary whole (Blanchard and Fabrycky,1981).
- A number of elements and the relationships between the elements (Flood and Jackson,1991).
- A set of different elements so connected or related as to perform a unique function not performed by the elements alone (Rechtin,1991).
- Consists of three related sets, a set of elements, a set of interactions between the elements, and a set of boundary conditions (Aslaksen and Belcher,1992).
- Any process or product that accepts and delivers outputs (Chapman, Bahill and Wymore,1992).
- The model of a whole entity; when applied to human activity, the model is characterised fundamentally in terms of a hierarchical structure, emergent properties, communication and control. An observer may choose to relate this model to real-world activity. When applied to natural or man-made entities, the crucial characteristic is the emergent properties of the whole. (Checkland,1993).
- A network of interdependent components that work together to try to accomplish the aim of the system (Deming,1993).
- The object of study, what we want to discuss, define, analyse, think about, write about and so forth (Kline,1995).
- US Federal Standard 1037C contributes the following two definitions, **1.** Any organized assembly of resources and procedures united and regulated by interaction or interdependence to accomplish a set of specific functions. [JP1] **2.** A collection of personnel, equipment, and methods organized to accomplish a set of specific functions (188) (FS-1037C,1996).
- An interdependent group of people, objects, and procedures constituted to achieve defined objectives or some operational role by performing specified functions. A complete system includes all of the associated equipment, facilities, material, computer programs, firmware, technical documentation, services, and personnel required for operations and support to the degree necessary for self-sufficient use in its intended environment (IEEE,1998).
- An integrated set of elements that accomplish a defined objective (INCOSE,2002). (INCOSE,2002) then adds, “People from different engineering disciplines have different perspectives of what a "system" is”.
- A system is a bounded object which is capable of responding to external stimuli, and in response to external stimuli a system's internal components interact with each other to produce internal and external effects (Scuderi,2004).

These definitions contain or imply the following minimum set of common elements:

- An external boundary
- Inputs
- Outputs
- Internal components
- Relationships between the components
- An external environment or containing system.

The definitions can be represented by the generic diagram shown in Figure 1 (Flood and Jackson,1991) which represents the creation of the system by taking an area of interest and drawing a boundary around that area such that anything inside the boundary becomes part of

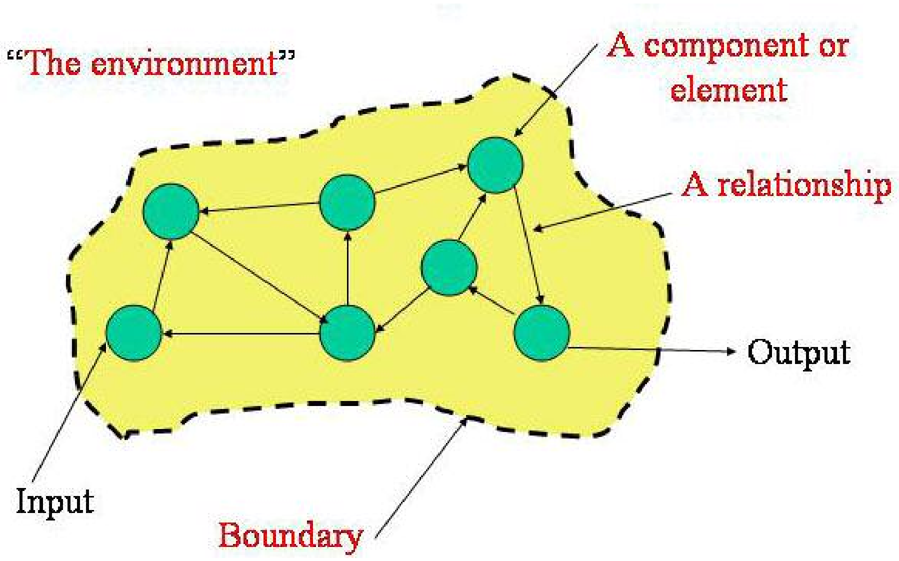

Figure 1 Generic representation of a system

the system and partitioning the area inside the boundary into subsystems or components. Note that Figure 1 does not refer to other attributes of systems mentioned in the definitions including emergent properties, purpose, and objectives.

If Figure 1 represents the system as defined in various ways, the question arises, why are there a number of different definitions? The first hypothesis in this paper postulates that the different definitions have come about as a result of the way people view problems (bound an area of interest) and each definition is a formulation of a problem.

Figure 1 however, is only a simple representation of the area of interest. Each component may itself be made of components; hence the components tend to be known as subsystems. Furthermore, the representation in Figure 1 assumes that external elements can be ignored for the purpose for which the system was constructed. This assumption is not necessarily true as we continue to discover. For example, in some land areas, pumping subsurface water to the surface lowers the level of the underground water table, which is not replenished by surface water seeping down after rainfall, but instead results in salt water seeping sideways into the water table to maintain the level. What's more, these external effects may show up with various time delays ranging from fractions of seconds to longer than centuries (Kasser,2002). Thus we change the boundaries of the system to incorporate external elements, initially considered as not having an effect on the system of interest, as we discover that they do in fact have an effect. The more we add to the system the more complex the system becomes.

A more generic representation of a system which includes the effects of components in or adjacent to the area of interest that affect the system is shown in Figure 2. Figure 2 reminds us of (Kline,1995)'s dictum that the system is only a representation of the real world, or in today's object-oriented parlance, an abstraction or a view of the real world. Kline uses the term 'sysrep' to reflect this situation and reserves the term system to describe the area of interest from which the sysrep is created.

Complexity

There seem to be two types of complexity as follows:

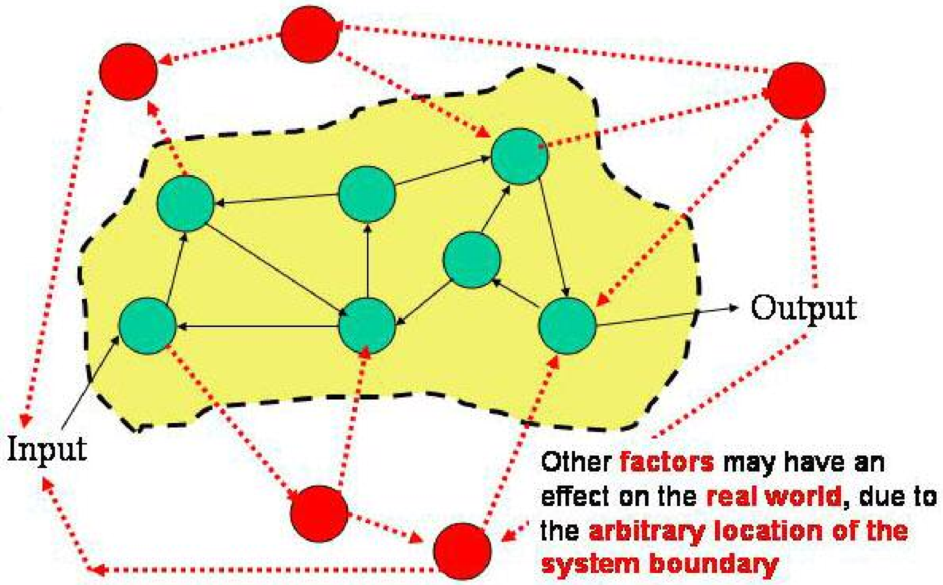

Figure 2 A more realistic representation of a system which takes external effects into account

- **Real world complexity** - in which elements of the real world are related in some fashion, and made up of components. This complexity is not reduced by appropriate abstraction it is only hidden.
- **Artificial complexity** – arising from either poor aggregation or elements of the real world that, in most instances, should have been abstracted out when drawing the internal and external system boundaries, since they are not relevant to the system. It is this artificial complexity that gives rise to complication in the manner of Rube Goldberg or W. Heath Robinson[1]. For example, in today's paradigm, complex drawings are generated that contain lots of information[2] and the observer abstracts information as necessary from the drawings. The natural complexity of the area of interest is included in the drawings. Hence the system is thought to be complex.

((Maier and Rechtin,2000) p 6) recommend that the way to deal with high levels of complexity is to abstract the system at as high a level as possible and then progressively reduce the level of abstraction. However, as (Maier and Rechtin,2000) point out, poor aggregation and partitioning during development can increase complexity (i.e. artificial complexity). Yet the concept that a complex system can be decomposed into a single set of smaller and simpler units omits an inherent characteristic of complexity, the interrelationships among the components (i.e. real-world complexity).

Cognitive filters

The process of creating a system should begin with the determination of which parts of the real-world area of interest are pertinent to the situation. The next step is to abstract out the non-pertinent elements to create the system or sysrep. This is the problem formulation process. The abstraction process

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[1] Cartoonists in the USA and UK who drew cartoons of complex systems designed to perform simple functions.

[2] DoDAF OV diagrams can be wonderful examples of complexity.

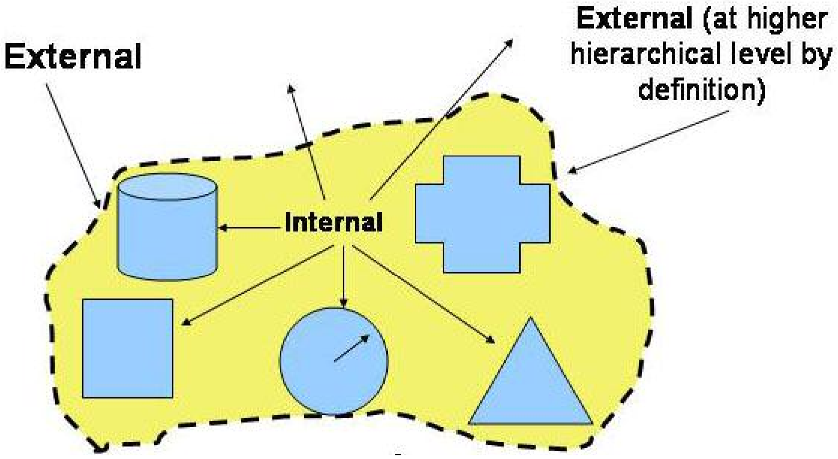

Figure 3 Internal and external views of a system

uses a filter to separate the pertinent from the non-pertinent. This filter is known as a "cognitive filter". Cognitive filters are filters through which we view the world. They include political, organizational, cultural, and metaphorical, and they highlight relevant parts of the system and hide (abstract out) the non-relevant parts. In some instances, they can also add material that can hinder solving the problem[3]. For example, the paradigm that requires the presence in a system of the following two characteristics (emergence and purpose) that were not shown in Figure 1 is a cognitive filter.

Emergence. (Hitchins,2004) defines emergence as "the principle that whole entities exhibit properties which are meaningful only when attributed to the whole, not to its parts". Figures 1 and 2 do not contain an explicit element that represents 'emergence' or 'emergent properties'. Emergence is a characteristic of the system, yet the notion (or requirement) that systems **must** have emergent properties is a cognitive filter. There seem to be three types of emergence:

- **Undesired** – functionality performed by the system that is undesired, also known as 'side effects'.
- **Serendipitous** – beneficial and desired once discovered, but not part of the original specifications.
- **Desired** – being the **purpose of the system** and can only be achieved by the combination of the subsystems or components.

Purpose. The notion that systems must have a purpose likewise is a cognitive filter. For example, a system containing four walls and a roof is a dwelling. Each component cannot perform the function of a dwelling on its own. The capability to function as a dwelling is the emergent property of the system made up by the walls and roof. It is also the purpose of the system. The purpose is not in the system, it is in the mind of the person drawing the boundary that creates the system.

The second hypothesis in this paper reiterates that the system, in the mind of the creator, is in fact a view of an area of interest in the real world through a cognitive filter which abstracts out of the real world only the elements thought necessary to be included in the system for the purpose for which the system was created.

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[3] For example, the differences between the Catholics and Protestants in Northern Ireland are major to many of the inhabitants of the country, but are hardly noticeable to most of the rest of the world.

Thus the various definitions of the word 'system' reflect a view of a problem through different cognitive filters by the creators of the definitions, namely Systems Engineering in the manner of (Wymore,1993). Moreover, once systems are defined they take on a life of their own. Forgotten is the reason for which they were created, and subsequent problems are viewed through the same cognitive filter, and, since these new problem situations may not exactly fit the cognitive filter, the problems are adjusted to fit the filter, namely the solution defines the need.

Introducing Simplification

This paper now hypothesizes that unnecessary excessive complexity is incurred by fitting a solution to a problem by the process of adjusting the area of interest in the real world to fit the cognitive filter[4]. Recognising that excessive complexity is a symptom of an underlying problem within the foundation of the current paradigm (Kasser,1996), this paper proposes that what needs to be done is instead of fitting a solution to the problem, we need to formulate the correct problem correctly and create an appropriate **set** of simple systems (from different viewpoints) as described below.

(Aslaksen,2004) writes

> *"Our choice of boundaries and interactions depends on what we are trying to understand and what we, as engineers, want to achieve by this understanding, so that system definitions are inherently subjective. In effect, defining a system is the first step in creating a* ***model*** *of some part or aspect of reality".*

The act of drawing an external boundary implies a containing system, so the concept of hierarchies is built into the definition. The act of drawing internal boundaries or partitioning the system defines the components or subsystems. The choice of partitioning is a major factor in the efficacy of any system description (Aslaksen and Belcher,1992). Consider the perspectives shown in the modified representation of a system as Figure 3.

The internal view shown in Figure 3 represents the "you can't see the forest for the trees" aphorism as well as demonstrating the reason for (Kline,1995)'s assertion that *"neither the top-down synoptic view nor the bottom-up reductionist view can, by itself, supply reasonable understanding of systems with hierarchical structure incorporating interfaces of mutual constraint and multiple levels of control".*

Furthermore, it shows that a complete view of any part of the system cannot be obtained from any single viewpoint inside or outside the system. Thus the use of internal views without any external views does not provide a complete understanding of a system and can lead to unnecessary complex solutions to the wrong problem. Consider the hierarchical view shown in Figure 4 (Kasser,2001). When System B is viewed externally from above, it is seen to be made up of three sub-systems. Yet when the Meta-system, which also has three sub-systems is viewed internally, the horizontal views through the subsystems it represents is commonly referred to as a System of Systems. Since the process of constructing systems from sub-systems ranges through many levels of hierarchy (from sub-atomic particles, though atoms, molecules, etc. all the way up to the universe), the complexity assumed for Systems of Systems is a direct result of the lack of external views of the system comprising the System of Systems. These external views, being outside of the system by definition, are at a higher hierarchical level than the component of the system, and must also be via various appropriate cognitive

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[4] This process is also known as "pattern matching" in the parlance of the object-oriented software paradigm.

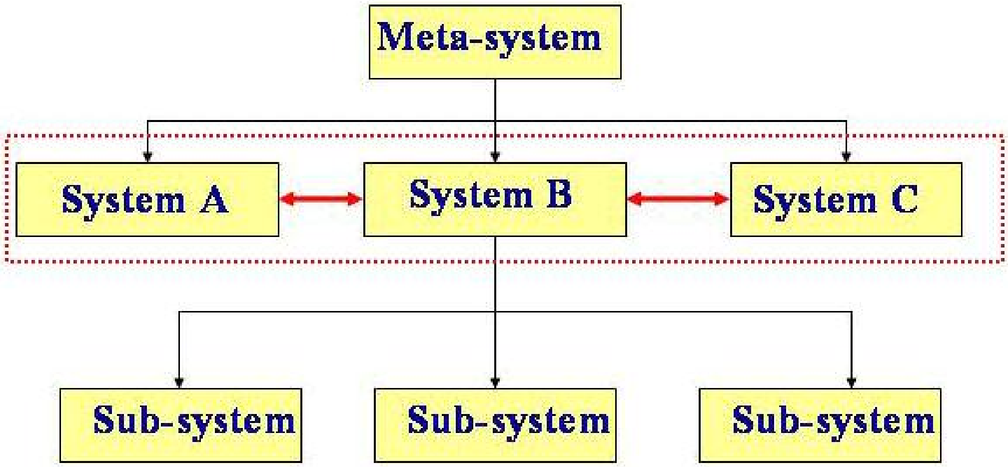

Figure 4 Views of a system.

filters. Moreover, each filter must provide a view that does not overlap the other views.

Thus in order to obtain a complete understanding of a system, there must be a number of internal and external viewpoints, each:

- separated in the space domain, so that no relevant part of the system is hidden and,
- simultaneous or synchronized in the time domain.

Moreover, if the behaviour of a system over time is being examined, a series of simultaneous space-separated, time synchronous views are required in order to obtain an understanding of the system.

In addition, optimal subsystem boundaries must be designed for Simplicity, namely:

- to maximize cohesion and minimize coupling (Ward and Mellor,1985),
- to abstract (hide) non relevant information, and,
- so that the maximum number of subsystems at any level of decomposition should generally be no more than seven (±1) to comply with Miller's Rule (Miller,1956) to facilitate understanding the system.

Yet another definition of the term system

This paper now proposes a semantically loaded definition of a system that incorporates the hypotheses of this paper, namely:

A system is an abstraction from the real world of a set of objects, each at some level of decomposition, at some period of time, in an arbitrary boundary, crafted for a purpose.

Consider the implications of the terminology used in the definition"

- **Abstraction** - used in its object-oriented meaning to remind us that a system is not the real world, but is Kline's sysrep and must always be viewed in that context.
- **A set of objects** - the components of the system.
- **Each at some level of decomposition** - each component may itself be an aggregate of components.
- **At some period of time** - not only do the system and its components have to be considered at the same period of time, but consideration has to be taken into account

that the area of interest represented by the system may change over time.

- **In an arbitrary boundary** - the boundary is crafted by the observer to enclose an arbitrary section of the real world. The boundary may appear arbitrary to other entities until the purpose of drawing the boundary is understood. The inclusion of the word boundary also points out that the generic system is a part of a meta-system or containing system.
- **Crafted for a purpose** - this is the part of the definition that really changes things. The system does not have to have a purpose. The boundary is defined by the purpose for which it is drawn in the mind of the observer.

Perspectives

This definition introduces new possibilities, currently being researched, some of which are discussed below.

Bridging the gap between hard and soft systems. The definition of a system proposed above seems to include or cover the various definitions of the term ‘system’ listed above. If this is correct, and the definition can cover most, if not all, of the other existing definitions of systems, then this new definition applies to both hard and soft systems and could serve as a baseline for bridging the gap between hard and soft systems.

Open and closed systems. The real world does not contain any closed systems. The typical textbook examples are clocks and the solar system. In the real world, clocks operate in a gravity field and the solar system is bathed in external radiation. However, when a boundary is drawn for the purpose of developing an understanding of the way the internal components of a clock or the solar system work together, then these systems can be considered as closed systems for that specific purpose.

Relationships between components. A set of objects does not become a system until a boundary is drawn around the set by some entity for some purpose. For example, two separate audio amplifiers on a circuit board do not constitute a system until a boundary is drawn around them to include them in a stereo system. To repeat, it is the act of drawing the system boundary that creates the system.

Mapping functionality onto components. The system boundary defines the functionality of the system. This functionality is mapped onto components (subsystems) as part of the design process in creating the physical system. However, some of the functionality may be a result of the emergent properties of the system. This can be represented in a mathematic format as

- **Functionality** = Area of system
- **Area of system** = (sum of functionality of all components + area of system not in a component)
- **Area of system not in a component** = emergent properties.

The emergent properties lie in the area of the system outside the components. If represented by a virtual component, such a virtual component could be added to Figure 2. Subsystem boundaries could also be drawn in some cases such that there are no gaps between components and hence no emergent properties.

Simplifying the process of systems analysis

The process of systems analysis is supposed to be a way of simplifying the complexity of the real world to allow us to manage the area of interest. This process however, instead of simplifying matters has tended to introduce complexity. As systems become more complicated (artificially complex) we add extra layers of control which makes the system even more complicated. This is a positive feedback situation.

The process of systems analysis starts by creating a system to represent the area of interest. We do this by abstracting a single system (sysrep) with a fixed boundary from a real-world area of interest. Once the system is defined, further views are generated of the system by abstracting out non-relevant information via various cognitive filters.

The complexity needs to be abstracted out when the drawings (sysreps) are produced to achieve Simplicity. For example, consider the United States Space Transportation System (Space Shuttle) and the International Space Station (ISS). Each is a complex system in itself, yet when solving the problem of docking a shuttle to the space station, all the underlying complexity that is not relevant to the docking problem is abstracted out. Thus, we abstract out everything other than information pertinent to

- Relative positions of the spacecraft
- Relative alignment in X, Y and Z orientation

This is an instance of Simplicity. Why can't we use the same paradigm elsewhere? We need to learn how to view things differently, namely adjust our cognitive filters for Simplicity not Complexity.

In object-oriented parlance, the real world is a data source; we deal with abstracted views of that data source. One specific view does not fit all purposes. The use of one specific system (view) introduces unnecessary complexity, since we have to fit all activities to that one view.

Abstracted views are systems. Why not just abstract views to help with the purpose directly from the real-world area of interest? Each abstracted view can be kept simple to facilitate its purpose, and a number of abstracted views will be needed for a complete understanding of the area of interest. In the world of Simplicity, there is thus no such thing as a (single) system that represents an area of interest. There are instead a number of systems, each of them dealing with some aspect of the area of interest.

As an example, consider the investigation of a rock. The system boundary is drawn at the surface. While determining the nature of the rock, various views can be used including:

- **Sight** – one looks at its colours.
- **Taste** – taste might give us some information about the chemicals in the rock.
- **Weight/mass** – might tell us something about its composition.
- **Touch** – the surface texture might be of interest.
- **Chemical analysis** – the components might be of interest.
- **Radiation** – could tell us something

Each view provides information that the others do not, helping to build up a complete understanding of the nature of the rock. If a rock was being designed, these views might also be subsystems of the rock.

Complexity vs. Simplicity

Is the world more complex today than in previous times, or is there just a perception that it is so due to unnecessary complexity? Within a given area of interest, different people may draw different system boundaries (INCOSE,2002). In the current paradigm that tends to happen for a number of reasons including communications failures. In the Simplicity paradigm most of the reasons might be stated as being due to the use of different cognitive filters.

System boundaries depend on the prerogative of the situation and are dynamic, not static. Attempts to establish and use a single static system boundary for all purposes result in unnecessary, and the perception of unmanageable, complexity.

Case Study Luz SEGS-1

This case study is an example of how the use of a set of different cognitive filters (out-of-the-box thinking) was a major contribution to a successful project. In the mid-1980's the Luz Group, a start-up joint Israel-American venture were developing the world's first commercial solar-fuelled electrical power generating system (SEGS-1). As the first of its kind, SEGS-1 initially only existed then as a vague concept. The station was to be installed in the Mojave Desert in California, but the Research and Development including prototyping was to be half way around the world, in Jerusalem.

SEGS 1 was intended to generate electrical power from the sun by focussing the sun's rays on about 600 parabolic mirror trough reflector collectors each about 40 meters long. The operation of each parabolic trough reflector was monitored and controlled by a microprocessor based local controller (LOC). Each LOC controlled a motor that positioned the parabola, and received information about the angle of elevation and the temperature of the oil in the pipe positioned at the focus of the trough. Oil was pumped through the piping, and as long as the LOC kept the reflector pointed at the sun within an accuracy of ±0.2 degrees the oil was heated. The hot oil was pumped thorough the field and into a heat exchanger to generate steam. The steam drove a turbine that generated up to 15 MW of electrical power. Although it was a complicated system, it still had a conversion efficiency of about 40%, greater than any alternative method of harnessing solar energy at the time. The situation was very uncertain (flexible), namely:

- Control would be single axis (elevation) only.
- Power generation efficiency dropped rapidly if the mirrors were not pointing at the sun. Moreover the mirrors would radiate the heat instead of absorbing it under off-pointing conditions.
- There were wide tolerances on the North-South alignment of collectors.
- The electromagnetic (E-M) interference environment was unknown.
- The sun sensors were mounted on the mirrors.
- There were no vibration specifications for the mirrors as a result of movement or for any other cause.
- There were few if any written specifications or procedures in the control and electronics department.

The initial traditional hardware-software based design approach was for a conventional central minicomputer design. The central minicomputer would act as the human interface to the system, perform the pointing position calculations for each mirror, then control all of the mirrors via a high speed data link[5] and microprocessor based interfaces (LOCs) at each mirror. These LOCs would position the mirrors based on control information from the central computer, and collect pointing angle and oil temperature information from each mirror. This design was complicated and high risk and the future of the start-up company was riding on meeting the schedule.

Recognising the futility of the conventional approach, the problem was formulated differently. The approach can be stated in several ways:

- A pattern match was made to a fleet of earth orbiting spacecraft and a central ground station.
- Out-of-the-box thinking was employed.
- An alternative design was chosen employing a different set of cognitive filters.

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[5] Ethernet was proposed, but was still in its infancy in those days, and expensive.

The subsystem boundaries were not drawn between hardware and software. An object-oriented component based approach was chosen instead. The functionality was distributed throughout the system which meant several software components were replicated in the LOC situated at each mirror instead of the central computer. Thus:

- The central computer predicted the approximate position of the sun and commanded the LOCs to deploy to the appropriate position.
- The LOCs were designed as "state machines"; the states being - rest, deploying, acquiring, tracking, and stowing.
- Each LOC was able to sense (acquire) the sun using the sun sensor mounted on its mirror.
- Each LOC was able to follow the movement of the sun using a lead-lag algorithm to move along with the sun to "flywheel" during short periods of cloud cover.
- The sensors used to detect the elevation angle of the mirrors were absolute position indicators instead of relative indicators based on a revolution count. This design approach allowed the LOCs to recover quickly in the event of power failures and spikes on the power line in the unknown E-M environment.
- The communications approach between the central computer and the LOCs was based on a sequential polling approach at relatively slow speeds using shielded twisted pair connectors and human readable ASCII text messages. The shielded pair cable took care of the unknown E-M environment and the and human readable ASCII text messages allowed for servicing the LOCs with palm held ASCII terminals that eliminated the need to develop special test equipment. Low data rate speeds were valid because the movement of the mirrors was very slow, as was the rate of heating of the oil.

Viewing the system through several different cognitive filters (including an embedded software approach) instead of the classic hardware-software approach meant that the pointing functionality was transferred from the central computer to the individual LOCs. This allowed the planned mini-computer to be replaced by a Z-80 based microcomputer costing $2,000, avoiding at least $US300,000 in hardware and software costs. In addition if the control link failed for a short period of time, the mirrors would continue to point at the sun and generate heat.

Yet another definition of systems engineering

The word system has been defined above. (AmericanHeritage,2000) defines the word "engineering" as:

1. The application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.
2. The profession of or the work performed by an engineer.

Thus by performing a simple algebraic word substitution, we have:

> *Systems engineering is the application of scientific and mathematical principles to the abstraction (from the real world) of a set of objects, each at some level of decomposition, at some period of time, enclosed in an arbitrary boundary crafted for a purpose*

This definition of systems engineering states that systems engineering is an activity, namely *the application of scientific and mathematical principles,* and seems to cover all five layers of systems engineering (Hitchins,2003) at all points within the two dimensional space defined by (Kasser and Massie,2001). The definition does not state anything about the nature or purpose of the "*application*" or the necessity to meet anyone's needs. To these authors, at least, it is more realistic than a definition that includes goals and purposes. The latter type of definition is an ideal to be aimed at, and not a pragmatic portrayal of the real world.

Summary

This paper has discussed ways of dealing with complexity by changing cognitive filters and redrawing boundaries. The hypotheses presented in this paper can be summarised as:

- The many definitions of a system are formulations of problem statements.
- The system is a view of an area of interest in the real world through a cognitive filter which abstracts out of the real world the elements thought necessary to be included in the system for the purpose for which the system was created.
- The process of adjusting the area of interest in the real world to fit the cognitive filter introduces unnecessary complexity, and recognising that excessive complexity is a symptom of an underlying problem within the foundation of the current paradigm (Kasser,1996); what needs to be done is to adjust the cognitive filter to view the area of interest and create an appropriate set of simple systems.

The insights presented in this paper can be summarised as:

- ▪ Systems cannot be totally understood from within the system even if viewed from a number of internal viewpoints.
- ▪ Several orthogonal views from an external (higher hierarchical level) perspective are also needed to completely understand a system.
- ▪ There's no such thing as a system *per se*! There's a map of some area of interest (aspect of the world) that we call a system for convenience (Kline's sysrep).
- ▪ Systems exist within hierarchies of containing systems.
- ▪ The area of interest cannot be separated from the real world.
- ▪ Defining the correct internal and external boundaries for the system and its components is critical.
- ▪ Complexity is everywhere but can be abstracted out for specific purposes, namely the way to deal with complexity is by changing the cognitive filter to a Simplicity paradigm.
- ▪ Within a given area of interest, different people may draw different system boundaries for different purposes at the same time.
- ▪ System boundaries are dynamic, not static, and depend on the prerogative of the situation.
- ▪ Attempts to establish and use a single static system boundary for all purposes results in artificial complexity.
- ▪ We do use Simplicity in a few instances, but it is not the current mainstream paradigm.
- ▪ "Complicatability" is the prerogative of the systems engineer.

Areas for future research

There are a number of areas for future research based on this paper including the following

- Hypothesis testing. This paper has stated a number of hypotheses based on the recognition that "excessive complexity is a symptom of an underlying problem within the foundation of the current paradigm" (Kasser 1996) and personal experience, and extrapolated on possibilities, perceptions, outcomes and thoughts the hypotheses have generated. Future research needs to be undertaken to test the hypotheses and investigate the possibilities discussed in this paper.

- Simplicity is out there in a few situations. The space station docking scenario and the LuZ solar field case study have shown that Simplicity does work. Future research needs to be undertaken to determine the nature of the process or processes for simplification so that Simplicity can become more widespread.
- Future research needs to be undertaken to determine if there is a mathematical expression for the minimum number and types of internal and external views necessary for a complete understanding of an area of interest.

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Biography

Joseph Kasser has been a practising systems engineer for 30 years. He is the author of "*Applying Total Quality Management to Systems Engineering*" published by Artech House. Dr. Kasser holds a Doctor of Science in Engineering Management from The George Washington University, and is a Certified Manager. Currently, he is the Defence Science and Technology Organisation Associate Research Professor at the Systems Engineering and Evaluation Centre at the University of South Australia (UniSA). He performs research into improving the Defence acquisition process, the nature of systems engineering and the properties of object-oriented requirements. He is also the Project Manager for the Defence Materiel Organisation customised section of the Master of Project Management postgraduate degree. He is a recipient of NASA's Manned Space Flight Awareness Award for quality and technical excellence (Silver Snoopy), for performing and directing systems engineering. Dr. Kasser also teaches systems and software engineering in the classroom and via distance education.

Kent Palmer is a practicing Systems Engineer working on SE Process Improvement and on various proposals in an organization that has achieved CMMI level three in Systems Engineering and level five in Software Engineering. It is thought to be the only organization to achieve CMM level five in Software twice and CMMI level five in Software once. He has a Ph.D. in Sociology granted in 1982 from the London School of Economics, University of London. His dissertation was titled: *The Structure of Theoretical Systems in Relation to Emergence.* He is now engaged in a part time external Ph.D. program in Systems Engineering at the Systems Engineering & Evaluation Centre (SEEC) (See http://www.unisa.edu.au/seec/) of the University of South Australia. His current research started in 2002 and is titled: *The Foundations of Emergent Meta-systems Theory and Practice.* Working papers in this research program are available at http://holonomic.info. Further papers in this research program regarding Special Systems Theory and Emergent Meta-systems can be found at http://archonic.net.