META-SYSTEMS ENGINEERING

A NEW APPROACH TO SYSTEMS ENGINEERING BASED ON EMERGENT META-SYSTEMS AND HOLONOMIC SPECIAL SYSTEMS THEORY

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Introduction

This paper introduces several different future extensions to the systems engineering discipline based on recent developments in general systems theory made by the author[1]. These recent discoveries recognize that there are many different schemas of intelligiblity besides the *system* schema, such as the meta-sytsem schema, the domain schema, the world schema, etc. that help us elucidate phenomena[2]. Each of these various schema calls for a different response from engineering, and thus engenders new engineering disciplines, or at least new approaches to the engineering of large scale systems. Among them are Meta-systems Engineering[3], Special Systems based Holonic Engineering[4] and Domain Engineering[5], World Engineering[6] and Whole Systems Design[7]. What is needed is a way to understand how these various kinds of schema and their associated engineering disciplines fit together into a coherent set of approaches. In this paper we will develop a theory of how this coherence of different

[1] See "Reflexive Autopoietic Dissipative Special Systems Theory" by Kent Palmer at http://server.snni.com:80/~palmer/autopoiesis.html or http://dialog.net:85/homepage/autopoiesis.html

[2] The approach taken in this work is further elucidated by several papers by the author written for International Society for the Systems Sciences (ISSS; http://isss.org) 2000 conference in Toronto. These papers may be seen at http://dialog.net:85/homepage/autopoiesis.html including the following titles "Defining Life And The Living Ontologically And Holonomically;" "New General Schemas Theory: Systems, Holons, Meta-Systems & Worlds;" "Intertwining Of Duality And Non-Duality;" "Holonomic Human Processes;" and "Genuine Spirtuality And Special Systems Theory"

[3] Van Gigch, John P. System Design Modeling and Metamodeling. New York : Plenum Press, c1991. See also Decision Making about Decision Making : metamodels and metasystems. Edited by John P. van Gigch ; with a foreword (metacomment) by Stafford Beer ; contributors, John P. van Gigch ... [et al.]. Cambridge, Mass. : Abacus Press, 1987.

[4] Jeffrey S. Stamps Holonomy: A Human Systems Theory. Intersystems Publications, Seaside, CA 1980

[5] See http://www.cse.ogi.edu/~walton/dom_eng.html and for a bibliography see http://i90fs4.ira.uka.de/bibliography/SE/domain.html

[6] Dyson, Freeman J.. Disturbing the Universe. New York : Harper & Row, c1979. See also Emergent Worlds Theory at http://server.snni.com:80/~palmer/emergent.htm

[7] Whole Systems Design Association at http://www.earthcorps.com/wsda/ See also Whole Systems Design course at Antioch University Seattle at http://www.seattleantioch.edu/WholeSystem/ See Whole Systems Design (WSD) web site at http://www.arashi.com/WholeSystem/

approaches based on the various schemas of understanding might be achieved.

From Super-system to Meta-system

A new trend in Systems Engineering is to begin to think about the difference between the "system of systems[8]," also known as the *super-systems*, engineering which deals with *mega-systems* or *macro-systems*, as opposed to the engineering of normal medium scale meso-systems or small scale micro-systems[9]. In fact, we might think of a whole scale of various levels of different sized systems which might call for different approaches to systems engineering due to the emergent properties that appear at the various scales. However, I would like to contrast this trend of considering *super-systems* as a special class needing peculiar methods, with another approach which instead emphasizes *meta-systems* (as another special class needing peculiar methods) and calls for the development of a particular sub-discipline of systems engineering that is not concerned with the effects of scale, so much as the effects of moving up a series of logical meta-levels from a system at any scale. This new discipline would be called **meta-systems engineering,** as opposed to systems engineering. As our basis for understanding what a *meta-system* might mean, we will take the Russell-Copi[10] concept of logical meta-levels developed in Principia Mathematica[11], which was also further developed by others such as Gregory Bateson,[12] who attempted to solve the problem of logical paradox, and we will contrast, as they do, the movement up toward higher meta-levels of logical type with the movement downward toward lower logical types. When we move to a meta-level it is very different from moving up or down a series of different nested scales of, for instance, "systems within systems within systems". As we move through the series of system levels there is a relative change of scale but at each level we are still dealing with *a system*, which is a template of understanding that we apply to certain types of phenomena. But when we move up to a logical type meta-level, i.e. to a higher logical type, then there is a strong difference in characteristics and interrelationships which cause us to understand that we are no longer dealing with a system, per se. Anthony Wilden has written a book called The Rules Are No Game[13], which expresses this qualitative and quantitative phase change very well. A *game* is seen to be a model of an idealized system that is of a higher logical type than all the specific instances of playing a particular game. Thus if the game exists at meta-level one, then the *rules* are at the meta-level two. This is very different from moving

[8] "Toward a Unified Systems Methodology for Australian Defense Systems-of-Systems" S.C. Cook, E. Lawson and J.S. Allison, INCOSE 1999 page 17; A Systems Engineering Process for Systems of Systems, Charles L. Roe, INCOSE 1999 page 20; "Archetecting Principles for Systems-of-Systems", M.W. Maier 1997 on line at http://www.infoed.com/open/papers/systems.htm

[9] By this is meant very small scale systems not micro-computer systems.

[10] Copi, Irving M.. The Theory of Logical Types. London, Routledge and K. Paul, 1971.

[11] Whitehead, Alfred North and Bertrand Russell, Principia Mathematica, Cambridge, University Press, 1910

[12] Bateson, Gregory. Steps to an Ecology of Mind. New York : Ballantine Books, c1972

[13] Wilden, Anthony. The Rules are No Game : the strategy of London ; New York : Routledge & K. Paul, 1987.

to a different game in the ontic[14] scale, say in a “game of games of games”. As you move up a level of ontic scale, one is still confronted with a game at the higher level. But when you move up an onto-logical[15] meta-level from any particular template of understanding, like the system, then you are confronted not with a game but with rules, i.e. something very different from a game which is intrinsic to the game but not the game itself. We call the rules the essence of the game. Rules describe the way you play a game and are definitely not the game itself as an abstraction(1) (meta-level one) or any concrete instance(0) (meta-level zero) of the play of the game. Rules exist at an onto-logical level(2) (meta-level two) beyond the game(1) where no players, pieces, or board exists except as terms of reference in the rules. Rules are static while games are dynamic. Rules seem arbitrary from the viewpoint of other games whose rules appear idiosyncratic or different. To take another example, the meta-level above spoken(0) language(1) is the grammar(2) of the language. Grammar is not a language itself but something else that describes the essence of a language by offering a set of constraints on the play of language. The idealization of a game(1) constrains the play of a particular game(0). If you go up another meta-level(2) one finds the categories of properties that exist which define a realm of possibility that the variation in the rules may take advantage of to define variations of the same game. For instance, a card deck is the basis for the invention of many different kinds of games of cards. The rules of different games take advantage of various aspects of the differences between the cards. With respect to language, one finds at the meta^2-level the categories of properties that constrain the grammars of all languages. These are properties like the various sounds that human beings can make with their vocal organs.

Quickly we realize that moving up to higher and higher meta-levels of onto-logical typing takes us into a very different realm from the systems of any ontic scale. Ontic systems of any scale may be characterized by an abstract gloss(1) that is a higher logical type than the concrete instances(0). At the meta^2-level one finds the rules, or constraints, that determine the essence of the system, game or language of whatever ontic scale is under consideration. If we move up to the next logical typing level(3) we find the meta-constraints that appear as categories of properties that determine the things that may function within a game, system or language. These meta-constraints underdetermine the lower level rule-like constraints which in turn underdetermines all possible particular instances of games, or systems or languages. What happens when we go through this exercise is that we discover that systems have essences that are constrained or determined by rules and that these rules are constrained by even higher level constraints on the categories of the properties of things that may give rise to games, or systems, or languages. Higher level general constraints on properties of things are quite different from lower level rule-like constraints on a specific system, game or language which gives rise to specific instances.

In order to be as clear as possible this can be expressed in the following way: The

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[14] Ontic is a term introduced by Heidegger in Being and Time which denotes the “beings” themselves without taking into account their Being. Ontos is the Greek word for Being. This is contrast with the Ontological which considers the Being of all beings as an Abstract gloss. Heidegger discusses ontological difference between the concept of Being (addressed by ontology) and the beings (considered ontic) that fall under that concept. See Heidegger, Martin.Being and Time. Translated by John MacQuarrie and Edward Robinson. London, SCM Press [c1962]

[15] Onto-logical expresses the fact that the concept of Being is directly related to logic which is concerned with the aspects of Being which are identity, reality, truth and presence. Rationality deals with all the aspects of Being in terms of relating our discourse to the world. Logic deals only the way that these aspects appear within the discourse itself.

categories of the properties of a system, game or language, in fact any gestalt, constrain the properties of things which can be cited in the lower logical typed rules which apply to the even lower logical typed players, pieces and the board that is governed by the rules. A Castling Move in Chess is a peculiar possibility given the properties of the King and Castle and their position on the board. The properties that distinguish the board, the pieces and the sides of the board, etc. make it possible to define a Castling rule which then can define actual play. Properties of things have a higher logical type than the rules that relate things, which in turn, have a higher logical type than the things that obey or disobey those rules. Anomalies occur when there are rule violations or when there are undefined situations that appear in actual play. An ad hoc case by case judgement that deals with lapses in the rules exists at the fourth meta-level.

We mention games, systems and languages in one breath because we believe that these are variations, or representations of the same template of understanding. Games, systems and languages all have the same basic schema. Each is a gestalt in which figures (forms) are seen on a background. In Games this is obviously the pieces on the board. In language it is the word on the background of the stream of speech. Systems are more general and thus correspond more directly to the form of the template of understanding itself. A system is a gestalt composed of anything that relates a figure to a background in a "systematic way", i.e. a way that is based on rules and the properties of the things that can be within the system including exceptions. Rules, properties and exceptions define the meta-levels of the system which may be mapped down on various phenomena in existence. The system[1] is a homeomorphism between various phenomena[0] that have a similar rule-based[2] property-based[3] and exception-based[4] configuration. We may draw this homeomorphism between languages and games as Wittgenstein does in his famous term language-game as a form of life.[16]

The Fragments of Being

In order to understand this series of meta-levels let us begin very generally and think not just of a *system*, but of any *entity*. Any entity can be designated to have Being. Being is the most general concept we can project on a thing, thereby turning it into an entity[17]. Being is a more general concept than the concept of system. Being covers all the templates of comprehension of things. It is the most general schema that we project on things. Being has traditionally four aspects: Reality, Identity, Presence and Truth. Reality is designated by judgement when we say *X is*. Identity is designated by discrimination when we say *X is X*. Presence is designated by reference when we say *X is here-now* or *This is X*. Truth is designated verification when we say *X is Y*. All of these statements are traditional ways of ascribing Being to things within the Indo-European worldview which is unique among the various historical worldviews in developing the concept of Being.

The study of the most general concept, i.e. Being, and its relation to things is called Ontology. Ontology and Epistemology are the normal constituents of Meta-physics, i.e. the philosophical description of what goes beyond physics. Epistemology tells us what we can know and Ontology talks about whether what we know is really, truly, identically present or not. In this century Continental philosophy has discovered that this most general concept, i.e. Being, is not unified but in fact is fragmented into an assortment of various Kinds of Being. An analysis of these kinds shows that the various

[16] Wittgenstein, Ludwig, Philosophical Investigations; Translated by G.E.M. Anscombe. New York, Macmillan [1953]

[17] i.e. a thing with ontos.

kinds of Being are naturally composed of a series of meta-levels along the lines of those we have seen in relation to systems, games and language. Thus it becomes clear that the distillation of the meta-levels of systems and systems-like things is not a specific property of systems, but of all things designated with Being within our worldview. This ontological property of logical layering is specifically rooted in all Indo-European languages. From this we can see that it should in principle be possible to subject all the possible templates of understanding to this same kind of meta-level onto-logical analysis and thus specify their articulation at the various meta-levels of manifestation.

The series of kinds of Being has a specific and determined order that is true for all things.

<u>Being's meta-levels</u>	<u>Bateson's series</u>	<u>Modalities of being-in-the-world</u>	<u>Associated Cognitive abilities</u>
Being^5 meta-level ULTRA Existence	This step into non-Being is ultimately unthinkable	empty handedness emptiness or void	cognitive inability
Being^4 meta-level WILD	Learning^4 *Learning to learn to learn to learn*	Out-of_hand	encom-passing
Being^3 meta-level HYPER	Learning^3 *learning to learn to learn*	In-hand	bearing
Being^2 meta-level PROCESS	Learning^2 *learning to learn*	Ready-to-hand	grasping
Being^1 meta-level PURE	Learning^1 *learning as an ideal gloss*	Present-at-hand	pointing
Being^0 meta-level entity	Concrete instances^0 of learning in the world	Orientation toward things	thing

Bateson, in <u>Steps to the Ecology of the Mind</u>, gives an excellent example of stepping through the series of meta-levels in his analysis of the meta-levels of learning. This may be done by starting with anything in the world. Heidegger tells us what the modalities of our being-in-the-world are in relation to the various meta-levels of Being. Merleau-Ponty points out some of the cognitive abilities in relation to things that exemplify these modalities. His view may be augmented by those of Levinas[18] to help fill out this column. Some of these concepts have been filled in by the author to complete the schema[19]. What we can see from Bateson's account of the meta-levels of learning is that when we start from concrete instances of learning and attempt to define learning, what then appears is a fairly static abstract gloss that serves as a definition of a cognitive capability in humans, animals and perhaps in machines. This abstract gloss is what appears at the level of Pure Being. Learning is considered as something that may be pointed out in the world which is present-at-hand, i.e. available to us in the world.

When we go up a level and attempt to understand how we *learn to learn*, this is

[18] Levinas, Emmanuel. <u>Otherwise than Being</u> : or, Beyond essence. Translated by Alphonso Lingis. Hague ; Boston : M.; Hingham, MA : Distributors for the U.S. and Canada, Kluwer Boston, 1981.

[19] Specifically the idea of the In-hand and Out-of-hand modalities that continue the series started by Heidegger of present-at-hand and ready-to-hand. Also the idea of Encompassing as the highest cognitive level to augment the idea of pointing and grasping developed by Merleau-Ponty and bearing contributed by Levinas.

where the rules or constraints on learning are discovered. Various constraints need different learning strategies to overcome or to manuever around them. Learning to learn is more than merely something we point out as a cognitive capability. It is something that we grasp in doing it. We relate to it in a fashion which is ready-to-hand, i.e. it is something we use directly to move toward the goal of present-at-hand learning. Learning to learn is like technology, it is an assorted means to an end. This meta-level is called Process Being. *Learning to learn* tells us more about the essence of learning, i.e. the constraints on learning that must be negotiated in order to learn how to learn.

When we move up to the next higher meta-level which is *learning to learn to learn*, things begin to become difficult to think about. It becomes more and more difficult to describe what is meant and to hold onto the concepts at this level. This level is called Hyper Being[20]. At this level we are relating to things via bearing and our modality of being-in-the-world is called the in-hand. It is called the in-hand because at this meta-level things transform into other things in our hands. This level defines the meta-constraints that determine the genetic unfolding of the thing which gives the thing its properties. Thus, this level defines the genetic unfolding of *learning to learn* within the world. This unfolding is something we bear and over which we have little real control. This, for instance, is described by Kuhn[21] in terms of paradigm changes in science. Scientific progress is made by continually expanding our horizon of ways of learning to learn from nature. But one has very little choice in the paradigm changes that occur because they are a social phenomena. One may accept or deny a paradigm, but little else.

Finally, at the last meta-level of learning, i.e. *learning to learn to learn to learn*, one loses control completely. This is seen as a total encompassing by the phenomena where everything is out-of-hand, i.e. out of control[22]. At this level there is no conceptual room to maneuver. Bateson calls it tantamount to personal enlightenment. This is because the constraints that determine the genetic unfolding change so that a different species of a thing is created with a different series of unfoldings. Learning^4 is complete because a constant transformation of the meta-essence of learning is continually changing. This is thought of as something only the “gods” could bear[23]. For human beings it would be tantamount to being subjected to a regime of permanent overwhelming fundamental change. When we get glimpses of this depth of change we call it a genuine emergent[24] event that restructures our world.

From this summary of the levels of Being, as applied to Bateson’s levels of learning, we can see that we move from the thing^{0} itself in the world, to a gloss^{1} of that thing at the first meta-level. At the second meta-level we find that the essence^{2} of the thing appears as the rule-like constraints that determine the use of the ideal gloss of the instances. At the third meta-level, we find the meta-constraints that determine the meta-essence^{3} properties of the

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[20] This name is taken from what Merleau-Ponty in The Visible and the Invisible calls the hyper dialectic between Heidegger’s *Process Being*, i.e. Being mixed with time, and Sartre’s *Nothingness*. See Merleau-Ponty, Maurice, The Visible and the Invisible; followed by working notes., Edited by Claude Lefort. Translated by Alphonso Lingis. Evanston [Ill.] Northwestern University Press, 1968.

[21] Kuhn, Thomas S.. The Structure of Scientific Revolutions. [Chicago] University of Chicago Press 1962

[22] Kelly, Kevin, Out of Control : the new biology of machines, social systems, and the economic world Reading, Mass. : Addison-Wesley, 1995

[23] In Greek myth the gods are continually changing their form. However, when human beings in myth transform as Daphne does, for instance. It is usually permanent.

[24] Mead, George Herbert, The Philosophy of the Present. Chicago, London, Open Court publishing Co., 1932.

things that underlay the expression of rules, which is how everything within the same category is constrained. Normally this refers to the genetic unfolding of the species of the thing. At the fourth meta-level, we find exceptions[4] to the rules and meta-rules that defy analysis.

Let us take the example of geometry. In geometry we have a series of n-dimensional spaces that are discovered by mathematicians in spite of the fact, we can only experience directly three, or four if you consider time a dimension. The series of n-dimensional spaces are nested in a way that has wonderful coherence and integrity. Points, lines, surfaces and dimensional forms are reused over and over again to produce higher dimensional figures. This nesting of higher and higher dimensional forms can be likened to the concept of the micro-system, meso-system, macro-system, super-system, mega-system etc. At each level there is greater and greater demand for integrity and coherence within the lower level systems which is necessary for the higher level system to work as a higher level ontic system rather than a mere aggregate. However, if instead we go in the orthogonal direction of thinking about meta-systems, then we find very different objects. For instance, given various mathematical figures[0] we might find an n-dimensional space, if we move to the meta-level we find the abstraction[1] of the discipline of geometry. But when we go to the next meta-level we find within geometry the process[2] of producing theorems by proofs and other activities that generate theorems about geometric mathematical objects. If we move up to the next meta-level, then we have the axioms[3] that all our geometry is based upon. Finally if we move up to the highest attainable meta-level of Being, we find exceptions[4] and contradictions. For instance, we really do not know about the essence of geometrical things unless we understand the process of producing proofs. In education geometry is composed of a series of static geometrical forms that we learn about in our classes on geometry. But to become geometers we must learn to do proofs. Learning to do proofs means mastering various techniques for learning about geometrical objects. When we understand proofs within the known realm of geometry then we can begin to question the axioms and postulates that define the domain of geometry. At this level we see that geometry had undergone paradigm shifts when it was discovered that the parallel lines postulate could not be proved. Geometers produced alternative geometries by allowing parallel lines to cross. It was discovered that there was a trace point of indecision[25] in the axiomatic basis of geometry itself. This point of indecision causes a process by which we learn how to learn to learn, i.e. a paradigm shift is generated within the field itself. This causes us to understand more deeply the axioms of geometry. These axioms are the meta-constraints that determine the properties of objects within the geometrical realm. They make possible the unfolding of geometrical proofs that effect the products of the proofs themselves. We define the objects of points, lines and surfaces and their properties and then take them for granted as part of our axiomatic platform. It is possible that there are exceptions or contradictions that may exist within an axiomatic system. These exceptions or contradictions exemplify the highest meta-level of Being. In geometry a contradiction might be generated by maintaining that parallel lines both cross and do not cross. We attempt to avoid such contradictions at all costs because they cause the whole discipline to collapse into chaos. An example of an exception is the dimensionlessness of a point. Everything in geometry has dimension except the point. The dimensionlessness of the point is very difficult to understand, but it is nevertheless

[25] See Derrida, Jacques. Of Grammatology Translated by Gayatri Chakravorty Spivak. Baltimore : Johns Hopkins University Press, 1976. Derrida calls these trace points "hinges" we can think of them as hinges between different possiblities.

assumed as an exception or contradiction within geometry that allows the geometrical formal system to work[26].

Ontic and Ontological Hierarchies

We have explored the various meta-levels of Being in order to show that this is a completely different horizon than that of the various scales of systems. We have seen that when we move in this direction we determine the essence (constraints) of the system and meta-essence (meta-constraints) of the properties of the things within the system that determine the forms that appear within the scale horizon. At the highest meta-level, exceptions in this lattice of constraints are identified, like Godellian statements for which no determination can be made as to whether they are inside or outside the formal system. Now, we will attempt to show how this onto-logical series applies to the definition of a system. This can be done by defining the horizon of scales as the ontic hierarchy. This means that it relates to the things that are designated to have Being without logical differentiation. Orthogonal to this hierarchy is another hierarchy of our ways of understanding the things in the world. We will call this the onto-logical hierarchy. It is composed of the fundamental comprehensible types of things we find. This hierarchy has the following levels:

[26] Another example of an exception is the Mobius band in which a surface only has one side or the Kleinian bottle in which the inside and outside surfaces are the same. Such anomalies challenge our intuitions about geometrical objects and teach us much in the process. For instance, the mobius strip and Kleinian bottle may be seen as lessons in the meaning of non-duality. Non-duality is a property of all holonomic systems. See Rosen, Steven M.. Science, Paradox, and the Moebius Principle : the evolution of a "transcultural" approach to wholeness Albany : State University of New York Press, c1994

Ontological Hierarchy

Pure *Deterministic* *Continuous*	*Process* *Probablistic* *Stochastic*	*Hyper* *Possiblistic* *Fuzzy*	*Wild* *Propensity* *Chaotic*
pluriverse	Over-determination	coherence	incoherence
kosmos	mapping	Transform-ations	blanks
world	Showing and hiding across horizon	projection	opacity
domain	filtering	assumptions	blind-spots
meta-system	dualities	resources	catastrophes
system	rules	properties	exceptions
form	Proof of theorems	axioms	anomalies
pattern	categorization	spectra	singularities
monad	isolation	cross-over	mutations
facet	distinguishing	integrity	flaws

Notice that what appears in this hierarchy are templates for an understanding of things. A system is one of those ways of understanding, but only one among several. Systems, as Rescher has shown[27], are based on intuitions about things that come from dealing with organisms in our environment. When considered very broadly, systems have many of the properties of organisms. Here we define a system as *a social gestalt*. This is to say it is a figure-ground relation seen by a group of people, or degenerately by a single individual. The *sine quo non* of such social gestalts are traditionally other groups of animals, or degenerately single organisms, or

[27] Rescher, Nicholas. Cognitive Systematization : a systems-theoretic approach to a coherentist theory of knowledge, N.J. : Rowman and Littlefield, 1979.

further degenerately plants, or at the limit of degeneration physical formations. We project the "system" template of understanding onto the ontic hierarchy. We may alternatively project other templates, or schema, of the onto-logical hierarchy onto the ontic hierarchy. For different phenomena, various onto-logical hierarchy templates may be appropriate. It is a matter of aesthetics or personal preference as to which templates of understanding are projected on which phenomena[28]. Much of the confusion in science occurs because different researchers project different onto-logical templates of understanding onto the same phenomena. The ontological hierarchy as a whole gives us a good measure of our progress in formulating a systems theory and in producing a systems engineering discipline based on such a theory. The standard for systems theory in our time is the *formal structural system* which covers the layers of the ontological hierarchy from system down to pattern. A form is an element in a formalism. We construct formalisms like geometry or logic and do proofs in these disciplines. A weaker standard of comprehension is an explanation which we give when we cannot do proofs. This standard operates at the level of pattern and is called structuralism[29]. It allows us to traverse discontinuities in forms or deal with time. The weakest standard of comprehension is the description of the system. We only give descriptions when we cannot explain or prove. We combine these three different standards of comprehension and call this the scientific approach to phenomena. A good generalized example of a formal structural system is George Klir's Architecture of Systems Problem Solving[30]. Science does not deal very well with any of the onto-logical levels from the meta-system upward or below the level of the monad. However some of these ontological levels are necessary for us to understand what science itself is. For instance, every system that science studies exists in some field defined by the meta-system. We mount our campaign to understand that system by creating a discipline which studies that class of phenomena. That discipline operates in a world shared by other disciplines. All those disciplines are gathered together in the university which contains all accepted disciplines. But beyond the university there may be many quasi-disciplines or proto-disciplines that are not accepted but which exist in the general economy of all possible disciplines including magical or other non-scientific approaches to things. On the other hand the monad is the lowest element of content in a pattern. Monads are the existant that the patterns are made of which structuralism finds to be the categorizable contents of form. Facets are the ways that these monads appear to each other in different contexts. The monad is projected by science as the non-reducible level that all other ontic scale levels are reduced to. We projected qualities such as earth, air, fire and water to be atomic until Democritus realized that it was possible that there were quantal atoms. We projected these ideal quantal atoms as the lowest level of reality until we discovered fundamental particles. Eventually we gave up this level for quarks which are never seen in isolation. Eventually we may give up quarks for something even more basic. Projecting the ultimate stratum level zero of substance[31] is part of the game of science which attempts to reduce everything

[28] Systems Engineering is a discipline whose members have a predilection for projecting the "system" cognitive template on things. A more mature discipline will recognize that this is merely one of many different fundamental types of comprehensional templates that are tools we might use to understand things.

[29] There are other kinds of pattern, namely value, sign and process. Process here means discontinuities in time while Structure means discontinuities in some plenum like space.

[30] Klir, George J., Architecture of Systems Problem Solving. New York : Plenum Press, c1985.

[31] Johansson, Ingvar. Ontological Investigations : an inquiry into the categories of nature, man, and society London ; New York : Routledge, 1989.

to that level. But in doing so Science reveals the levels of ontic emergence that segments the ontic hierarchy into various recognizable levels of phenomena which have different characteristics and different kinds of relations. Each of these ontic levels is the underdetermining basis of the next higher level. "Supervenance" is the technical term in Analytical Philosophy for the mapping down of a higher level ontic configuration onto a lower level ontic configuration. Each mapping down is partially determined by the lower level and partially non-determined. To the extent that it is not determined there is room to maneuver and room for new non-reducible properties and relations to appear which exemplify emergent phenomena.

Systems Engineering focuses on the emergent aspects that appear at any particular ontic level, however we discern it. It is interesting that systems are assemblies of physical components with specific properties and actions. These components have both functional and agent shadows. As we build up the ontic hierarchy by assembling components, we only arrive at the next higher ontic emergent level when the functional hierarchy and the agent hierarchy meet the assembly hierarchy at the same point. We normally think of function as a single kind of thing that subsumes and supports the intentions of the users of the system. Agency on the other hand relates to the various autonomous actors that work together to perform the functions. The separation of distributed agency and the gatheredness of the intention supporting uniformity of function form a spectra along a single dimension orthogonal to the dimension of physical assembly. The Agency shadows of the component is the basis for what is called the physical architecture while the Function shadows of the physical assembly is the basis for what is known as the functional architecture. When the two shadow architectures that appear within the general economy overflows, the restricted economy of the components that inhabit space and time merge at some ontic level of assembly. Then we have an emergent property appear. If some aspect of the assembly breaks, then we de-emerge[32] from this point of the articulation of emergence. The unity of the functionality of the system fragments and the agency may become uncoordinated. If there are multiple kinds of emergence that occur, then there is really a kind of function related to each kind of emergent characteristic that finds itself integrated at some level of the systems articulation.[33]

In general, given any phenomena that is considered as a system, i.e. a social gestalt, which means a gestalt for some group of people[34], then we move up to the meta-systemic level. At that level we are breaking apart that system into its constituent elements and, thus, deconstructing it so that its emergent properties disappear and the field within which those elements swim appears instead. That field sees the sub-systems as gestalts on the ur-ground of the meta-system. Any specific thing can be thought of in relation to the various meta-levels of Being. But if we take each of the templates of comprehension (cognitive schemas) up that series of steps, we will get very different

[32] This idea of de-emergence originates with Bob Cummings (robert.j.cummings@boeing.com).

[33] This explanation owes much to David Poole of Altair Systems (dpoole@altaira.com) who has developed a state machine method for defining satellite and booster information systems architecture for use in ground systems.

[34] Here we ground "systems theory" and thereby "systems engineering" in a kind of social phenomenology ala Alfred Schutz and Aron Gurwitsch. Schutz considers the implications of phenomenology for sociology and Gurwitsch update's Husserl's work to add the awareness of gestalts beyond forms. A combination of the two gives us a feel for what a social phenomenology of systems should be like. See Gurwitsch, Aron. Field of Consciousness. Pittsburgh, Duquesne University Press, 1964. See also Schutz, Alfred, The Phenomenology of the Social World., Translated by George Walsh and Frederick Lehnert. [Evanston, Ill.] Northwestern University Press, 1967

results as seen in the table above. For the system which is like a language-game we will find the rules at the level of Process. Beyond that we will find the meta-rules that determine the properties of the things that are allowed within the system. Beyond that we find the exceptions and contradictions that are the violations of the property constraints and game rules.

When we explore the onto-logical meta-levels of the various templates of understanding we find some very interesting differences between the various meta-levels. Looking at the Formal Structural System as a whole we see at meta-level^2 rules, theorems and categories. At meta-level^3 we see properties, axioms and spectra. At meta-level^4 we see exceptions, anomalies and singularities. If we look carefully at these three levels we see the nesting of the levels fairly clearly. Notice that as one moves to higher meta-levels of the system, one finds rules and then properties of things within the system, and then exceptions. But when we look at forms, then there are proofs of theorems and then axioms and then anomalies. The forms are shapes of things with properties. As we advance up the meta-levels of system we approach something that feeds into our understanding of form. Similarly, when we look at pattern, then we move from categorization of contents, to spectra of qualities, then to singularities. Axioms concern the minimal elements from which the forms are built up. Those minimal elements can be categorized according to qualitative criteria as a way of approaching the actual spectra that lie below the categorizations. When we look at monads then we move from isolation, then to cross-over then to mutation. Isolation allows us to see the minimal discernable quanta of the phenomena that makes up the spectra. When we try to determine this exactly, it normally leads to a recognition of a bleeding over into other minimal discernables called cross over or tunneling between isolateable elements. The cross-over or bleeding out of minimal discernables causes us to look at how we distinguish one thing from another and thus calls into question the integrity of our minimal discernables. Cornelius Castoriadis talks about Magma[35] as the non-determinable proto-order of things beyond our projections of order. The lowest bound of the onto-logical hierarchy of templates of understanding is the ontic magma beyond all our discriminations. Deleuze and Guattari[36] talk about the rhizome of interconnections that produces a labyrinth of distinctions and produces monadic discriminations which, taken together, are impossible to organize completely. Facets and Monads are projected beyond experience to explain the fact that we comprehend determinate things within the buzzing confusion of our experience. All the things that do not fit into our projections are pushed out into Wild Being at every threshold of comprehension. It is out of Wild Being that the things that change our view of the world arise. Emergent events move through each of the levels of Being on their way into our world. They many percolate up through any of the templates of understanding. A genuinely emergent event passes through all four meta-levels[37]. Events that do not involve all four levels of Being are called artificial because they do not fully reprogram our organization of the world at some level of understanding.

A similar nesting can be seen occurring at the upper thresholds of understanding. Systems can only exist if they have the

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[35] Castoriadis, Cornelius, The Imaginary Institution of Society. Cambridge, Mass. : MIT Press, 1987. See also World in Fragments : writings on politics, society, psychoanalysis, and the imagination edited and translated by David Ames Curtis. Stanford, Calif. : Stanford University Press, 1997.

[36] Deleuze, Gilles and , Félix Guattari. A Thousand Plateaus : capitalism and schizophrenia. Translation and foreword by Brian Massumi. Minneapolis : University of Minnesota Press, c1987.

[37] See The Structure of Theoretical Systems in Relation to Emergence. London School of Economics, University of London, Dissertation, 1982 by the author.

necessary resources. Resources are the meta-level beyond the duality or complementarity of meta-systems that is the meta-level of the meta-system itself. The meta-system is normally a set of integrated complementarities of complementarities that defines the environment or ecosystem that the system finds itself within and inhabits. Meta-systems cannot be fully dominated by domains but their filtering of systems is based on higher level assumptions. Domains attempt to construct a restricted economy with a unified ideal viewpoint on the phenomena with which they are concerned. Domains attempt to tighten up the filtering done by the meta-system on its constituent systems by increasing rigor. Filtering is done by the production of theories that connect phenomena in ways that are coherent for the domain. Theories are ways of looking at the phenomena which is based on implicit and explicit assumptions. The Domain is an incarnation of the general projection of the worldview on a specific set of phenomena. This projection is a reification of the showing and hiding of the world. The world establishes the horizons across which the phenomena manifest. Moving from one horizon to another is a fundamental transformation at the level of Kosmos. The kosmos is a mapping exercise that takes us beyond our direct experience and attempts to be all inclusive. These maps attempt to give global coherence to all phenomena of a certain kind. These coherences arise from the over-determinations of phenomena in the general economy that cannot be dominated completely by the kosmos and thus is called the pluriverse because it is constructed of multiple intersecting universes along the lines that David Deutsch suggests in The Fabric of Reality[38]. The highest level of understanding bumps into the incredible variety of things that exists within the universe and not one grand unified scheme can account for all the variety even if it could account for the general laws of nature that underlay the arena in which the variety interacts.

It is important for Systems Engineering as a discipline to realize that the “system” is not the only schema or template of understanding that we might apply to the emergent ontic hierarchy. The “system” fits into the “formal structural system” and this has a dual in the “world domain meta-system”. These two dual templates apply to experience and are augmented by two pairs of other templates that are projected beyond experience in order to make sense of experience. Kosmos attempts to unify all the phenomena of the world through maps, and what it fails to map falls off our model of the earth into the pluriverse which is a catchall for all we do not understand about the universe. Monads attempt to supply the ultimate level of reduction at whatever ontic level that it is projected onto, whether it is organisms, atoms, fundamental particles, quarks, sub-quarks, etc… The facet governs everything that falls outside the monad’s capability of reduction. Within experience there are six thresholds of comprehension[39], at least notionally. In other words this is only a model of the thresholds taken from the current literature of Science in the broad sense which includes hard and soft sciences. There are endless variations of these various thresholds in the literature. But for our purposes we can focus on these six experiential thresholds by which we can comprehend the phenomena we see “out there” in the realm of the ontic emergent hierarchy. The “formal structural system” (notice that these are mentioned in the order of their power of explanation of phenomena) is well understood[40]. What is not well

[38] Deutsch, David, The Fabric of Reality : the science of parallel universes-- and its implications New York : Allen Lane, c1997.

[39] From world down to pattern, because kosmos, pluriverse and monad, facet lie outside experience, i.e. are a priori.

[40] Wilden, Anthony. System and Structure: essays in communication and exchange. London, Tavistock Publications, 1972.

understood is the inverse dual of the formal structural system that appears as the combination of the _domain world meta-system_. Notice that Systems Engineering is attempting at this point in time to establish itself as a discipline with a specific domain. The domain is a filter and the meta-system is the field which underlies this filter, while the world is a showing and hiding structure based on horizons. When we consider the environmental impact of our work on systems, then we are dealing with the meta-systemic field. What we have not yet taken on is the project of World Engineering. World Engineering would have to look at the interactions and side-effects of all possible systems that appear on the horizons of the world. World Engineering is still the stuff of science fiction[41]. If we were to take on that task then there are many things that we would have to consider within the auspices of our discipline that are not considered now. We have not taken ownership of the interspace between the systems we build. World Engineering would consider the relation between the various systems of whatever scale and would take into consideration the interaction of these systems.

Systems and Meta-systems

At this point in the history of the development of our discipline, systems engineering, we tend to focus on *systems* because there has been a good formal structural systemic basis developed by science in the last few hundred years. Systems are descriptive of any phenomena seen as a social gestalt[42]. Systems have broad applicability because they can be applied to any phenomena that is construed as a social gestalt. Thus it is an extremely malleable template of comprehension. It is also highly structured due to the fact that it consists of rules and properties at its meta-level. Proofs and categorizations have greater explanatory power but rules have greater structuring power through the modeling of constraints at both the Process Being *essence* and Hyper Being *meta-essence* levels. Axioms are arbitrary and have limited extent so that proofs have extremely narrow scope compared with structures or systems. Categorizations are also arbitrary and though they have broader extent than proofs, their extent is still extremely limited comparatively. Spectra appear to be grounded in phenomena but properties formulate the qualitative content of the phenomena so that they can be understood and incorporated into our systems as variables. Thus, in general, although the explanatory levels of systems are weak, they give us quite a bit of organizational leverage. That is why we tend to focus on this level when we turn to engineering projects and away from doing science. That is when we leave discovery work and begin building and construction.

We get a fairly high leverage when thinking about things in terms of systems and this compensates for their lack of explanatory power. It seems that there is a tradeoff between explanatory power and structuring at the meta-levels of Being. This is why we do not call our discipline Forms Engineering or Patterns Engineering. But what we fail to appreciate in many instances, is that there is something to be gained by looking at the discipline and meta-systemic levels as well. This essay suggests going one step further than usual by addressing the meta-systems level which, as it turns out, is complementary to the systems level. Meta-systems are environments, ecosystems, situations, milieu or contexts. We see them when we deconstruct the super-system and allow its

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[41] See Dyson on terraforming the planets.

[42] Understanding the schema **system** as a "social gestalt" implies social construction and the social invention of systemic phenomena, which implies that systems are not objective characteristics of the phenomena but that they are projected onto the ontic substrate of the phenomena by social groups.

subsystems to be seen within the internal environment of the super-system. The meta-system indicates the field within which the system arises and within which it interacts with other systems. Meta-systems are inherently complementary and thus not unified in the way that systems are unified. Meta-systems always contain duals, they supply the resources within the arena that the systems need to operate in order to function and interact. They provide the communication between systems within that arena. A good analogy is the operating environment within which applications run in computers, so called “operating systems,” which are really meta-systems. Formally, the meta-system is to the system as the universal Turing machine is to the Turing machine. It is an environment that runs Turing machines that it reads from tape and adjudicates between them providing them resources as necessary. Meta-systems engineering is the natural complement to systems engineering. Systems engineering is concerned with the unified product that is to be built. Meta-systems theory is concerned with the environment that this product will go into and its side-effects in that environment[43]. It also considers each level of the ontic hierarchy to be a deconstructed super-system, which when taken apart, gives us a meta-systemic environment for the sub-systems to arise within and interact with each other. Thus, meta-systems engineering is what holds sway as the product is being developed. The meta-system describes the design landscape of all possible product designs and how the selected designs arise and interact within the development process. Processes live inside of meta-systems which produce systemic products. The complementarity between process and product is similar to the complementarity of the system and meta-system. The complementaity between quality and quantity are similar. Product quality is improved by measuring the process that develops that product. Whenever you find complementarities it is a sign of a meta-system. For instance, the complementarity between reading and writing of data in the Turing machine and in computer systems, is generally a sign of an interaction with that machine’s environment. Environment related operations are always complementary.

Due to this complementarity between systems and meta-systems, we cannot have a systems engineering discipline without a complementary meta-systems engineering discipline. And it turns out that this is exactly the discipline we need in our time, because it is the side-effects of systems in the environment that is the fundamental problem facing our discipline. We design systems but ignore the meta-systemic implications of those systems and sometimes that leads to unintended consequences. Meta-systems, though, are not just ecosystems but also relate internally to our systems design and to the design process. Thus each supersystem, when de-emerged, turns into a meta-system for the sub-system components. It is this phenomena that leads us to consider the combination of systems and meta-systems holonomic. This is to say that together they describe what Arthur Koestler called Holons[44]. Holons are things like organs in the body that are parts from the perspective of things above them and wholes from the perspective of things below them in the ontic hierarchy. Systems, when decomposed, give us meta-systemic fields which spawn sub-systems and so on down the ontic hierarchy. In other words the ontic hierarchy is constructed out of the action of transforming from system to meta-system or vice versa. The power of the complementarity between system and meta-systemic views is that it generates the ontic hierarchy that encompasses everything that we ascribe to

[43] See “Industrial Ecology and Systems Engineering – a perfect match?” O.A. Asbjornsen INCOSE 1999 page 35.

[44] Koestler, Arthur, Janus : a summing up. New York : Random House, c1978.

Being within our worldview.

Meta-systems engineering does not look at building things, but examines taking them apart. It is deconstructionist[45] in the postmodern sense. In fact, one interpretation of Postmodernism[46] is the realization that there is a general meta-systemic economy that operates outside of the historically sanctioned restricted economy of ideas, values, significance etc[47]. One of the things this postmodern viewpoint takes apart is "systems engineering" itself. When we look at systems engineering as a discipline we see that it is composed of a core related to systems theory and a periphery that is made up of many specialties that come from the various domains in which systems engineering is applied and these are integrated into the various kinds of systems we build. The sine quo non of our approach to building things is the integration of emergent effects from multiple disciplines. Thus, the set of possible domains from which we draw can be seen as the meta-system to the system we are attempting to build. Systems engineering itself is a field with many sub-disciplines making up a rich fabric of concerns. The meta-system is what mediates between the domain of systems engineering and its various sub-domains. What has hardly been imagined yet is that systems engineering encompasses all the various fields of human endeavor by which we attempt to project the template of understanding that allows us to see systems in the world. The complementary template is that of the meta-system which sees the underlying proto-gestalts of gestalts on the ur-field beneath the figure ground relations that make up the system. These two templates together allow us to define holonomics which is the study of holons and holarchies of holons. This gives rise to what is sometimes called *whole systems design*[48] which is a subfield of systems engineering that is concerned with the production of holonic systems, i.e. systems that fit into the whole and are whole themselves. The ideal of such systems are what George Leonard[49] calls *Holoidal* systems which are systems that have attributes like a hologram in which each part functions based on an image of the whole system. Holoidal systems are the opposite of aggregate systems which are blind to the wholes that they are a part of. Whole systems design is directed at understanding holoidal systems and building them such that the world is seen as nested wholes each of which is holoidal in relation to the upper level wholes of this different kind of ontic hierarchy. In this kind of hierarchy we have increased the level of coherence demanded from the meta-system coherence of fields to the coherence of domain filters or to the level of the coherence of the world itself where the horizons are seen to be coherent. As we do this the nature of the ontic hierarchy changes. Systems Engineering puts together forms so that they create coherent gestalts. Meta-systems engineering wants the sets of gestalts to be coherent. Domain engineering wants those gestalts to be coherent with respect to a selected filter of phenomena, sometimes called a paradigm. World engineering wants all the horizons upon which phenomena appear to be coherent within a worldview. What starts out as a bland composition slowly takes the form of a hologram as we go

[45] Derrida, Jacques. Of Grammatology. Translated by Gayatri Chakravorty Spivak. Baltimore : Johns Hopkins University Press, 1976.

[46] Plotnitsky, Arkady. Complementarity : anti-epistemology after Bohr and Derrida. Durham : Duke University Press, 1994. See also Plotnitsky, Arkady. In the Shadow of Hegel : complementarity, history, and the unconscious. Gainesville : University Press of Florida, c1993.

[47] Bataille, Georges, The Accursed Share : an essay on general economy. Translated by Robert Hurley. New York : Zone Books, 1988-1991

[48] See Whole Systems Design Association at http://www.earthcorps.com/wsda/

[49] Leonard, George Burr, The Silent Pulse : a search for the perfect rhythm that exists in each of us New York : Dutton, c1978.

up the levels of the ontological hierarchy and imagine a different kind of engineering at each level. A Kosmic engineering, if that were possible, would ask for all the worldviews to be coherent within the universe.

Equally as we move down the ontological ladder we encounter greater and greater degrees of decohernece where monads, the minimal discernable elements, are the ultimate conceivable fragments of existence. Systems Engineering attempts to increase coherence one notch from the level of forms in the world because its structuring in the meta-levels of Being provides a big jump in terms of effective coherence. But this coherence carries with it the emergent properties that are realized by the systemic whole. It is necessary to allow a complementary de-emergence to occur which will give coherence to the set of gestalts rather than merely to the gestalt itself.

Moving from separation to gatheredness we go to even higher level notches on the coherence scale by applying the ontological hierarchy to the ontic hierarchy step by step. This takes us more and more deeply into *whole systems design*[50] as a branch of Systems Engineering. Systems Engineering should stress its foundations in Systems Theory. Unfortunately these foundations are lost to most of the "systems engineering" community because they never studied systems theory. It is strange to think that the theory of systems is not required for professionals to practice systems engineering. This is like saying that electrical engineers do not need to know the theory of electrical circuits in order to design them. Hopefully, eventually systems engineering will rediscover its roots in academic General System Theory. Then the discipline will no longer feel adrift with no scientific foundations. General Systems Theory is the meta-science of all science that treats systems in general in a scientific manner. General Systems Theory is to Particular Sciences as Mathematical Category theory is to the various Mathematical Categories, like sets, groups, lattices etc., that are the objects of various branches of mathematics. But Systems Engineering should also recognize its sister discipline, Meta-systems Engineering, which should be based on a General Meta-systems Theory that should complement general systems theory. Unfortunately, this discipline does not exist at the moment, unless we consider the study of ecosystems[51] an example of such a study restricted to how biological organisms interact within their environment. However, we can still pay attention to meta-systems within our practice, by considering the implications of what we are doing for the relevant environment and by considering the design field itself out of which our solution arises. We can also think about how the demergent fields within which sub-systems operate as part of the super-system.

[50] Whole Systems Design homepage is at http://www.arashi.com/wsd/

From Meta-systems to Special Systems

We define holonomics to be the study of holons and holarchies both within the world and in theory. We note that through the recognition of duality there has been progress in holonomics that the reader should be aware of. What we find when we look at systems and meta-systems as a duality, is that the system is a whole greater than the sum of its parts, while the meta-system is a whole less than the sum of its parts. The meta-system has *lacks* and *deficiencies* that are exactly what is needed for the system to fit into it. We build the nested levels of our super-systems by allowing each level to unfold into a meta-system that sustains its sub-system parts. By moving back and forth

[51] Pickett, Steward T., Jurek Kolasa, and Clive G. Jones, Ecological Understanding. San Diego : Academic Press, c1994.

between these views, we develop a holonic way of seeing the *systems of systems*. However, we should note that there is a third possibility. That is the possibility of wholes exactly equal to the sum of their parts. This brings us to the mention of Special Systems theory which should be the third discipline that is developed between the complementarity of General Systems Theory and General Meta-systems Theory. *Special Systems* deal with anomalous systems in which the whole is exactly equal to the sum of the parts. Such systems are aggregative yet still whole. There are three examples of such systems, they are called Dissipative, Autopoietic and Reflexive. Dissipative special systems are equivalent to what Ilya Prigogine[52] calls "Dissipative structures" which are negentropic. Autopoietic special systems are self-organizing and are equivalent to what Maturana and Varela define as self-producing systems[53]. Reflexive special systems are social in nature and correspond to the kind of reflexivity that John O'Malley describes in The Sociology of Meaning[54] and which Barry Sandywell describes in his Logological Investigations[55]. Each of these special systems function as a whole that is exactly equal to the sum of its parts but in different ways. The autopoietic system represents homeostatic balance through the maintenance of the system's own organization. Dissipative and Reflexive systems are a pair which are each out of balance separately but together provide a model of dynamic balance. Autopoietic systems can be seen in terms of the model of the Perfect numbers while Dissipaitve systems can be seen in terms of the model of the Amicable numbers, and Reflexive systems can be seen in terms of the model of the Sociable numbers. The perfect numbers are those rare examples where the factors of a number add up exactly to the number itself without deficiency or surplus. Amicable numbers are plentiful and are examples of two numbers whose parts add up to each other. Sociable numbers extend this same trick to groups of numbers higher than two. Perfect and Amicable numbers were known in the Greek era and were symbols of the possibility of perfect systems. Sociable numbers were only discovered in 1914 and so extend these kinds of numbers to a set that reflects the holonic properties of all three special systems. However, the special systems theory has firmer grounding in mathematics than this. The series of HyperComplex algebras give us our mathematical model for the special systems.

Meta-system	Sedenion or higher non-division Algebras This algebra has one real and fifteen imaginary numbers and loses the division property
Reflexive Special System	Octonion Algebra This algebra has one real and seven imaginary numbers and loses the associative property
Autopoietic Special System	Quaternion Algebra This algebra has one real and three imaginary numbers and loses the commutative property

[52] Prigogine, I. in collaboration with Isabelle Stengers.. The End of Certainty : time, chaos, and the new laws of nature. New York : Free Press, 1997. See also Prigogine, I.. Order Out of Chaos : man's new dialogue with nature. Toronto ; New York, N.Y. : Bantam Books, 1984.

[53] Maturana, Humberto R., Maturana and Francisco J. Varela. Autopoiesis and Cognition : the realization of the living Dordrecht, Holland ; Boston : D. Reidel Pub. Co., c1980.

[54] O'Malley, John B. Sociology of Meaning. London, Human Context Books [1972]

[55] Sandywell, Barry. Logological Investigations London ; New York : Routledge, 1996 volumes 1-3

Dissipative Special System	Complex Algebra This algebra has one real and one imaginary number in conjunction.
System	Real Algebra This algebra has one real number

There are also anomalous physical systems that display the properties of these rare *special systems*. Dissipative systems are seen in nature in the phenomena of Solitons. Autopoietic systems are seen in nature in the phenomena of the Cooper pairs in superconductivity. Reflexive systems are seen in nature in the phenomena of the Bose-Einstein condensate and other macro-quantum mechanical phenomena. Given the existence of these anomalous physical examples and mathematical underpinnings, Special Systems theory is as scientific as any discipline might hope to be.

Special systems theory gives rise to a new kind of Holonic Engineering which attempts to build systems, such as self-organization, with the properties of the special systems. These are the properties of intelligent living social systems. One definition for a Holonic System is "A system which self-organizes and evolves to dynamically optimize survivability, adaptability, flexibility, efficiency and effectiveness"[56]. Holonic Manufacturing Systems[57] have this kind of ideal. Special Systems theory is the first unified theory of these kinds of systems. Holonic Engineering makes use of the Special Systems theory foundations to build systems that are in aggregate still whole, that self-organize and socially interact as intelligent agents, and which introduce order into the world through their mutual action.

Beyond the special systems themselves there is also the form of the Emergent Meta-system[58] that describes the joint action of normal entropic systems with the various special systems. Emergent Meta-systems are swarms of holonic agents that create, mutually interact, form gestalts, explore possibilities and then vote through mutual annihilation on which possibilities should be realized in the next cycle. Emergent Meta-systems Engineering looks beyond the synchronic holarchy to a diachronic holodynamic formation which designs itself in a way similar to the workings of the grouped genetic algorithm[59]. It is one thing to talk about autopoietic self-production and it is quite another to talk about self-design[60]. Self-design can only be achieved by a swarm of holoidal holons that interact to produce their own organization as a social collaboration. The individual elements collude with each other to assure their continued existence over time. Such a system assumes discontinuity instead of the continuity that our systems normally assume. Swarms of Intelligent social agents produce each other and mutually interact and then recognize their own design and elaborate the various possibilities for the development of that design until they vote which possibilities to act upon. Emergent meta-systems provide us with a model of the "ultimate" System that engineers itself as part of its functioning. The engineering of self-designing systems

[56] Holonic Solutions: http://www.holon.com.au/

[57] http://hms.ifw.uni-hannover.de/

[58] Emergent Meta-systems are similar to the Self Generating Systems of Ben Goertzel. See Goertzel, Ben. Chaotic Logic : language, thought, and reality from the perspective of systems science. New York : Plenum Press, c1994.

[59] See Emanuel Falkenauer Genetic Algorithms and Grouping Problems (Wiley 1998)

[60] This is like the distinction that Barry Sandywell makes between *social construction* verses *social invention.* He distinguishes between the pre-reflexive, reflective and reflexive which correspond to the dissipative, autopoietic and reflexive special systems.

goes beyond autopoiesis to Autogenesis, i.e. the self boot strapping of organization that produces the self-producing system.

Future Kinds of Engineering

Now that we have defined various strange kinds of engineering that appear as future possibilities, let us look at them together once more. Systems Engineering is a discipline which leverages from the System onto-logical template of understanding which has a great deal of structure at its meta-levels as compared with the lower level templates such as form and pattern. We can think of other disciplines such as Form Engineering and Pattern Engineering as sub-disciplines below Systems Engineering. But beyond Systems Engineering, we can also imagine Meta-systems Engineering, Domain Engineering, World Engineering. At each level we are introducing greater and greater coherence into the ontic hierarchies of the systems we build. And yet there is another dimension that we need to recognize which is the dimension of the special systems that moves out orthogonally from the duality of Systems and Meta-systems. In the special systems we find the true meaning of holonomics as the study of holons, not in the sense of holoidal systems, but in the sense of aggregates that are separate but whole at the same time because their whole equals the sum of their parts. Special systems engineering concentrates on creating intelligent social agents that organize themselves, but these agents do not design themselves. This is to say that such agents have a static essence. When we consider giving these agents a dynamic essence by creating a meta-essence that can design itself, then we can see the possibility of an emergent meta-systems engineering of systems that design themselves and thus boot strap their own order into existence through autogenesis.

All this may sound like science fiction, but it turns out that the foundations of this twenty first century engineering exists today in the form of special systems theory and emergent meta-systems theory. So let us start this new century by exploiting this future engineering that has serendipitously come to us now[61].

Conclusion

You can think of this paper as an introduction to several strange new kinds of engineering disciplines that may grow out of systems engineering as we know it today. It is based on recent advances in Systems Theory. Systems theory should be the foundation of our systems engineering discipline. However, too few of us know about any of the recent advances in General Systems Theory which could serve as a basis for better engineering of systems. This paper attempts to bring some of those cutting edge advances into focus by projecting the systems engineering disciplines that may emerge in this new century.

About the Author

Kent Palmer is a Principle Systems Engineer at a major Aerospace Systems Company. He has a Ph.D. in Sociology concentrating on Philosophy of Science from the London School of Economics and a B.Sc. in Sociology from the University of Kansas. His dissertation on The Structure of Theoretical Systems in Relation to Emergence[62] focused on how new things come into existence within the Western

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[61] This same thing has been said of SuperString Theory which is billed as a next century science that fell into the 1990s. Speical Sysems Theory and Emergent Meta-systems theory is similarly a future systems theory that has fallen into our own time by serendipity.

[62] http://server.snni.com:80/~palmer/disab.html You man also try http://dialog.net or http://think.net for any of the web related material.

Philosophical and Scientific worldview. He has written extensively on the roots of the Western Worldview in his electronic book The Fragmentation of Being and the Path Beyond the Void[63]. He had at least seventeen years experience[64] in Software Engineering and Systems Engineering disciplines at major aerospace companies based in Orange County CA. He served several years as the chairman of a Software Engineering Process Group and is now engaged in Systems Engineering Process improvement based on EIA 731 and CMMI. He has presented a tutorial on "Advanced Process Architectures[65]" which concerned engineering wide process improvement including both software and systems engineering. Besides process experience, he has recently been a software team lead on a Satellite Payload project and a systems engineer on a Satellite Ground System project. He has also engaged in independent research in Systems Theory which has resulted in a book of working papers called Reflexive Autopoietic Systems Theory[66]. A new introduction to this work now exists called *Reflexive Autopoietic Dissipative Special Systems Theory*[67]. He has given a tutorial[68] on Meta-systems engineering to the INCOSE Principles working group. He has written a series on *Software Engineering Foundations* which are contained in the book Wild Software Meta-systems[69]. He now teaches a course in "Software Requirements and Design Methodologies" at the University California Irvine Extension.

[63] http://server.snni.com:80/~palmer/fbpath.htm
[64] http://server.snni.com:80/~palmer/resume.html
[65] http://server.snni.com:80/~palmer/advanced.htm
[66] http://server.snni.com:80/~palmer/refauto2.htm
[67] http://server.snni.com:80/~palmer/autopoiesis.html
[68] http://dialog.net:85/homepage/incosewg/index.htm
[69] http://server.snni.com:80/~palmer/wsms.htm