The Foundations of General Schemas Theory

SEEC Ph.D. Research Program
University of South Australia

1) Focus of Research Program

My research concerns the mathematical and philosophical foundations of the new discipline of Systems Engineering. If Systems Engineering is to be accepted as a discipline in its own right by other scientific disciplines then it must be able to show that it not only has its own subject matter, but its own approach to that subject matter. There is a general movement within INCOSE to more firmly establish the place of Systems Engineering within the academic community by identifying its unique foundations. As these foundations are established they will be leveraged to improve Systems Engineering methods, processes, and products as we move beyond the traditional methods that are now practiced. Presently, when we attend Systems Engineering courses we are not taught foundational material, we are presented with traditional methods and processes that have been generally shown to work in practice. Other accepted disciplines in universities teach a combination of methods, processes, *and* foundational material which gives a basis in knowledge along with practical techniques. Systems Engineering deserves the same attention. So the question that has been asked many times at various INCOSE forums is this: Is there a foundational basis for Systems Engineering? My research is an attempt to discover the foundation of knowledge from which Systems Engineering may be built up as a discipline which will provide a knowledge basis that can be philosophically justified and mathematically secure. I hypothesize that a foundational basis for systems engineering can be found in advanced philosophical and mathematical realms, and that Systems Engineering will be established as a twenty-first century academic discipline as these foundations are discovered and defined.

2) What my research will contribute to Systems Engineering

a) Who cares about this work and Why

As noted above I see my research as responding to a need recognized by INCOSE leadership. I was first involved in a Workshop at the LA INCOSE convention by a special interest group devoted to trying to understand the Foundations of Systems Engineering Theory. Then I was subsequently invited to give a series of talks on this subject at the CSER 2004 conference. My presentation is available on my Website and is entitled “The Foundations of General Schemas Theory”. For INCOSE leadership the question is one of academic respectability, which is also one of the goals of the CSER conference: *to establish that worthwhile research is being done within academia on topics of interest to Systems Engineering programs within universities*. However, as far as I have been able to ascertain few of these research projects are directed at foundational issues. Beyond the Systems Engineering leaders in INCOSE, I believe that *Systems Engineers in general* should be interested in the foundational work being done by Ph.D. candidates, because without a fundamental theory, the progress of Systems Engineering as a discipline will be very slow. In general, engineers first learn physics as a theory and then learn to apply the physical properties discerned by these theories to their

engineering work. For example, without a fundamental theory of Complex Artificial Systems we would be reduced to trial, error, and experience based methods as a means to our ends. We have physical theories and engineering methods for lower level engineering disciplines to guide our work, but we have no such theory at a higher level other than what Systems Theory gives us. That means that systems engineers have nothing to turn to other than traditional methods *without* foundations as a means to our ends (which are the designs and integration of complex artificial systems, and systems of systems). All Systems Engineers should be concerned with the fact that their discipline is at the stage of *craft* and has not yet become a scientifically based discipline. All Systems Engineers should be engaged in the struggle to turn Systems Engineering into a scientifically based professional discipline. One step toward this is the establishment of the Systems Engineering Body of Knowledge, this Body of Knowledge needs to be enhanced with scientifically sound theories that describe how Complex Designed Systems and Systems of Systems are produced and how they work. My research is a first step in this direction.

b) Proposed Contribution to the Body of Knowledge of Systems Engineering

The first phase of my work is dedicated to establishing what I call General Schemas Theory. This is a generalization of Systems Theory as it relates to other schemas, such as Pattern, Form, Horizon, Domain, World. We are living in a time when the term *System* has lost its force because it is applied to everything indiscriminately, and the only way to give meaning back to the word *system* is to explore its relation to other schemas that exist, (as they have always existed as a basis for design within world culture) although they have not been recognized previously as forming a meta-system of their own. This leads us to realize that what we call Systems Engineering, is really *Schemas Engineering based on Schemas Theory*. In other words, limiting ourselves to a single schema as a basis for design is a fundamental limitation that is ill advised because we actually use different schemas as a basis for design all the time. Yet this is unrecognized because of the privileging of the schema of the system. Now, once we have recognized that there is a general schemas theory that can be a foundation for schemas engineering, it is significant to point out that schemas are intimately tied to the mathematical concept of dimensionality. I have discovered that when we look at the set of schemas as a whole and relate them to the mathematical concept of dimensionality, there are two schemas per dimension and two dimensions per schema. This gives us the fundamental tie into mathematics that we need in order to give our design work a mathematical basis. Dimension is a very fundamental mathematical concept that informs our design work within the framework of schemas in myriad ways hither to unrecognized.

Once we have understood that there is a fundamental connection between schemas theory and dimensionality in mathematics we learn that mathematics itself has to be reconsidered at a fundamental level. During my research, I discovered that the basis of mathematics in Set theory is incomplete. This is because Sets as a mathematical category has an *unrecognized dual* in Mass Theory. Currently mathematicians propose that the opposite of the Set Category is just another image of the Set called $\mathbf{Set^{op}}$. But in fact there is evidence that the real dual of the Set is the Mass which evidences itself in linguistic usage but does not appear to be developed in Mathematics. When we recognize this dual of the Set as a Mass (and once we recognize that historically) then we will come to understand that masses have their own logic called Pervasion Logic which was developed in India. We will then see that instead of having one basis which is The Set with Syllogistic Logic, there are in fact two basis for mathematics. When we develop this second basis for mathematics in Mass Theory

along with its logic, then we see that many of the problems encountered by Systems Engineering (and Schemas Engineering) can be addressed by this wider mathematical concept. In essence, when a system is in execution or operation, it can be conceived as a mass operating within a pervasion logic, which allows for the System (or Schema) that is being designed to be conceived of in terms of Sets and Syllogistic logic. Many of the problems that we have in Verification, Validation, Integration and Operations come from the fact that we do not have a way of thinking about the system execution and operation because we cannot bridge the gap between system conceptual design and actual system execution (of operation). The intention of my research is to lay the groundwork for developing this new way of thinking about mathematics in terms of the duality between Set and Mass approaches.

If all this is true then it means that Systems Engineering must transform its self concept from a singular 'schema centric' approach to considering the broad spectrum of schemas as a basis for design. Systems Theory is the basis of systems design. At this point systems theory courses are nonexistent within the Systems Engineering curricula. And, on a more general level, Schemas Theory should be taught as the basis of Systems Engineering because we actually use all the schemas in our design work. Thus learning about the nature of the various schemas should be the knowledge base for a Systems Engineering curricula. Bringing the discipline of Systems Engineering into the realm of academia will engender transformations in other various academic disciplines in unexpected and emergent ways For example, such would be the case with mathematics where Schemas Theory and mathematical dimensionality have led me to explore the mathematical category of sets in relation to their dual in Mass Theory. The fact that Systems Engineering (as a discipline) could have this effect on other disciplines, shows that it is a fundamental discipline with its own basis poised between schemas, the mathematics of dimension, and the mathematics of sets and masses.

From a philosophical perspective, the schema has a long history of continuing development, starting with Protagoras, then followed by Plato in the Timaeus, then by Aristotle in De Anima, then by Kant in Critique of Pure Reason, and finally by different modern Continental Philosophers such as Deleuze, Badiou, and others. Part of my research involves tracing the origins of the concept of the schema within this philosophical tradition and its trajectory. Schemas are undervalued and underdeveloped within the tradition compared to concepts such as Logic and Mathesis.

My research has gone on to consider Design Methods and their relation to the schemas by identifying Meta-methods. Meta-methods are more general than the methods normally identified with SysML and UML (which are currently celebrated within our design tradition). This leads to a refinement of our concept of design within the context of Schemas Theory and Schemas Engineering.

Hopefully, my research will contribute to Systems Engineering and Integration by introducing a fundamental way to think about Systems Engineering Design and Integration in terms of Set and Mass dualities and their associated logics. Furthermore these logics will be used to ground General Schemas Theory in the use of methods and meta-methods which will facilitate the process of conceptual design and the practical construction of systems. This will give designers a basic knowledge of the types of schemas and a rich language that will be useful for producing complex artifacts that embody *all* the schemas, not just the systems schema.

My research puts Systems Engineering in the context of modern Continental Philosophy, Advanced Mathematics, Advanced Systems Theory, and Logic in order to paint a picture of what the future discipline of Systems Engineering can become. The idea is to take fundamental discoveries in

mathematics and philosophy made in the last century and use them to better understand the nature of Systems Engineering. Then, we can apply our new understanding to more fully develop Systems Engineering and this will help define its niche in the frontier of human knowledge in the twenty first century.

c) Proposed Contribution to the Practice of Systems Engineering

Systems Engineers are involved in creating some very complex systems, and now with the "System of Systems" expectations, we are attempting to make these already complex systems inter-operate to produce even more complex systems. In my papers I have argued that we are missing a perspective on what the nature of "Systems of Systems" can be because we do not understand the nature of systems well enough. I have pointed out that merely using the Schema System by itself does not give a full picture of the complexity of the artificial complexes we construct. Rather I have noted in a previous INCOSE paper that there is a dual to the System Schema which is not well understood. I have named this dual the Meta-system. By thinking in terms of category theory and mathematical categories we can identify duals of known categories in order to discover unknown categories. The duality of Set and Mass is of this nature. But there is also a dual to the System called the Meta-system. The Meta-system is organized differently from the system; an example of this would be the difference between the operating system of a computer and the application of the computer. An interesting result of my research is the fact that both of these schemas are embodied by Turing Machines, *but* that the Turing Machine is viewed differently in the two cases. *A recent set of my papers on Methods states that the same Methods that are used for understanding Systems may be applied to understanding and designing Meta-systems due to their embodiment in Turing machines*. I then added to this notion by identifying dual meta-methods that apply to the whole hierarchy of schemas in addition to these two schematic levels. I also identified the 'method like' approaches that appear at other schematic levels. Understanding the nature of the methods available and what their scope and applicability are is important for practitioners. This work on methods also has implications for understanding the nature of Design and Integration as well.

If a foundational theory for Systems Engineering can be advanced then it is possible that the practitioner will gain by having a reference model by which to gage his own design and integration efforts, rather than just past experience. The research I am engaged in attempts on many fronts to find such a foundational theory and some progress has been made as evidenced by my working papers -- many of which are available on my website. Other papers that are part of my dissertation but not available on my website are named and can be produced for inspection.

For more information see http://holonomic.net See also http://archonic.net

Kent Duane Palmer,
Ph.D. LSE, U. London 1982
kent@palmer.name
714-633-9508
Box 1632, Orange, CA 92867 USA