

# **Systems Science Foundations for Systems Engineering**

## **Schemas Theory as a Constitutive A Priori Paradigm Shift for Systems Engineering and other Disciplines with Ramifications at the Ontological and Epistemological Levels**

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As an introduction to this series of working papers on Systems Science for Systems Engineers and Software Engineers we will look carefully what a Paradigm Shift is and how this is related to Ontological and Epistemological levels of abstraction. We use the work of Michael Friedman in his Dynamics of Reason<sup>1</sup> as a basis for trying to understand how Schemas Theory can be a Paradigm Shift for Systems Engineering. Friedman discusses in detail Paradigm Shifts in Physics and how the work of T. Kuhn has profoundly shaped our view of how our theories are underpinned by paradigms which is a network of presuppositions that make it possible to relate the theories to experience within the enterprise of Science. One of our basic assumptions is that Philosophy of Science that we associate with the names of Lakatos, Popper, Feyerabend, Kuhn applies as much to Engineering as Science. Science and Engineering are two sides of the same thing. Today Science needs the technological infrastructure to make its experiments. Engineering uses knowledge developed by Science to produce its products. There is not much effort put into attempting to develop a philosophy of Engineering independently. Basically Engineering produces the technological infrastructure that supports not just the affordances of our modern lifeworld but the Science itself as a human enterprise in all its aspects. If we accept that Engineering is not isolated from Science but is in fact another face of the same cultural complex within our modern society, then it is clear that Engineering can undergo Paradigm Shifts just like Science can. However, we expect paradigm shifts in Engineering to be somewhat different from those in

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<sup>1</sup> Friedman, Michael. Dynamics of Reason. Stanford, Calif: CSLI Publications, 2001.

Science. One of the differences is that Paradigm Shifts in Engineering are usually generated by the innovation process by which new patentable technologies are developed. For instance, there was an explosion of Software and Business Model related patents which changed fundamentally our idea of the value of Software Engineering technologies and ways of doing things on the Web. But here we are going to discuss the situation in Systems Engineering which is a meta-discipline over and above both Software Engineering and other forms of Engineering which contribute to the building of parts of Systems. Systems Engineering is distinguished by its responsibility for the working of the entire system that is being built with help from the various other Engineering disciplines. Traditional Systems Engineering practices has recently been codified in the Systems Engineering Body of Knowledge. And we should mention that an update was recently made to the Software Body of Knowledge as well. Thus the baseline has been established for these two disciplines in terms of what they consider the knowledge upon which they are founded and which they use in their practice. In the Release of the Systems Engineering Body of Knowledge there was an addition of material on Systems Science, Systems Thinking, and Systems Practice and their relations to each other. And as part of the effort to introduce more about Systems Science to Systems Engineers this tutorial was commissioned by the INCOSE working group on Systems Science. But in this series of tutorials we take the position that in order for Systems Engineering to absorb Systems Science there is a paradigm shift that is necessary toward Schemas Theory. Schemas Theory is the next level of abstraction up from Systems Theory. It turns out that this possible move to a higher level of abstraction does not seem to have been considered previously. What we are arguing in this series of working papers is that the Paradigm Shift to Schemas Theory is necessary for Systems Engineering, and other disciplines. We want to try to clarify how this can be by referring to the work of Michael Friedman who accepts Kuhn's account of Paradigm Shifts between Normal and Revolutionary Science that produce incommensurate discontinuities in the tradition.

Friedman identifies three levels<sup>2</sup> of abstraction within a tradition in terms of the operation of Science which are the empirical level where laws of nature confront the tribunal of experience in experimentation and testing, the constitutive a priori level of principles where a fundamental spatio-temporal framework is established which embodies a paradigm which is relatively stable basis for Normal Science, and finally the philosophical meta-framework which provides guidance for the orientation of the transition from one framework to another. Now it is interesting that Schemas Theory is precisely a spatio-temporal framework because Schemas are templates of understanding different spatio-temporal scopes. What is different from the previous framework is that it was seen as a plenum which was homogeneous as objective Spacetime which is the present-at-hand view projected by science which has not changed since Descartes discovered the duality between geometry and algebra and then that was used to establish Newtonian Absolute Space and Time which was recognized as a Synthetic A Priori by Kant. From the time of Kant this has not been

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<sup>2</sup> [Dynamics of Reason](#) p. 45

challenged even though there was the fusion of Space and Time into Spacetime by Einstein, still Riemann curved spacetime was considered the warped backdrop to all physical phenomena. The greatest challenge to this came from Heidegger who in Being and Time showed that our tradition had forgotten other types of Knowledge originally recognized by Aristotle. These levels were identified by Heidegger as the ready-to-hand and dasein itself. Heidegger associates the present-at-hand with the mathmatico-geometric spacetime of the homogenous plenum of the objective backdrop on which all physical processes occur and this is the basis of our epistemic knowledge produced by modern science. But human beings do not actually live in that space from a phenomenological perspective and thus he identifies a different type of space associated through the ready-to-hand with techne and its control over poiesis. To that space we have a mass-like relation rather than a set-like relation which we experience as an affordance of useabilities within the technological infrastructure that we deal with through circumspective concern as a totality. And beneath that user spacetime there is a further deeper level associated with Dasein itself which is related to phronesis of praxis. What Heidegger tells us which is similar to what Husserl alludes to in *Krisis*<sup>3</sup> which is that science has separated itself from the lifeworld of human beings by projecting more and more abstract spacetime frameworks. And it has reduced human encounters within the world to the relations of subjects to objects where subjects themselves are seen as objects. As Nietzsche says subjects are objects turned inside out. So in order to reclaim these different levels of knowledge known by the Greeks and recorded by Aristotle and Plato Heidegger attempts to go back prior to the subject/object duality and to focus on the part of the human being that projects templates of understanding through interpretations on phenomenological experience. Science and Engineering are caught up in the relation between present-at-hand and ready-to-hand modes of Being. Essentially Science sees everything as present-at-hand and Engineering adopts this attitude as well trusting implicitly in Science. But Engineering creates the technological infrastructure that we must relate to in a ready-to-hand manner though circumspective concern relating to it as a totality rather than as a unity as the present-at-hand does. Engineering produces the furniture of the world which makes many things possible that would be impossible for us otherwise, but the very fact that it is furniture for us, i.e. an environment with technologically supported affordances, means that means that our fundamental relation to it is mass-like rather than set-like. Where humans come into contact with the technological infrastructure is where allowances are made for human sensibilities by considering us as users and offering us human systems integration. However, the rest of the technological infrastructure is treated as present-at-hand by engineers. The level of disclosure that is Dasein prior to either the present-at-hand or ready-to-hand modes which Heidegger calls Existential is utterly ignored by both Science and Engineering, but this is the realm where we exercise judgment with regard to our praxis, which is

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<sup>3</sup> Husserl, Edmund. *The Crisis of European Sciences and Transcendental Phenomenology: An Introduction to Phenomenological Philosophy*. Evanston: Northwestern University Press, 1970

not dependent on technology or knowledge of science<sup>4</sup>. This is the realm where we encounter each other face to face without the blinders engendered by either science or technology. Aristotle talks about this in terms of Friendship which he says must be among equals and not based on either pleasure or usefulness. The aesthetic hands off pure presence of the present-at-hand can be seen as associated with pleasure, Kant called it a disinterested pleasure related to the Beautiful. The usefulness of other human beings can be seen as associated with the ready-to-hand that is associated within Practical Reason with the hypothetical (final and efficient causes) and categorical imperatives (formal and material causes). According to Aristotle friendship is between equals and must be carried in an attitude that each wants to give Good to the other without receiving recompense. This is another way of thinking about the realm of the disclosure of the *mitsein* (being with) in which *dasein* (being there) is immersed prior to its degeneration into the Heideggarian reified and inauthentic *Das Mann* (They, One).

Now what is interesting is that the schemas break up the homogeneous plenum of assumed objective spacetime into levels of scope in which different organizations of spacetime appear that are different, in such a way that it agrees with phenomenological experience. This is a way to bring our view of spacetime back from being purely abstract projections by science and engineering into line with our experience of the lifeworld. But this necessity only appears when we try to raise engineering from specialist disciplines to a meta-discipline responsible for integrating the work of various disciplines. Already Systems Science has done this for the scientific disciplines and attempted to produce a transdisciplinary science of systems in general outside of the various domains in the university. When we appeal to Systems Science as the foundation of Systems Engineering we are in fact addressing the meta-discipline of science as the basis for the meta-discipline of engineering. But something interesting occurs when we make this move which is quite unexpected. For Systems Engineering to absorb Systems Science it is necessary to organize the output of the more than half century of work that was done in Systems Science, because we find Systems Science to be fragmentary due mostly to the fact that it never had a department, and was always carried on by institutes within the university setting. Thus unlike Software Engineering that can look to Computer Science as a basis in science, Systems Engineering's counterpart was never a universally accepted discipline and therefore was fragmented throughout the other disciplines. Thus in order to synthesize Systems Science for absorption by Systems Engineers and others interested in Systems Thinking we need something like Schemas Theory to perform that bridging between Systems Science and Systems Engineering. But the bridge causes us to go up one level of abstraction beyond the System to the Schema. At that point we realize that there are lots of different schemas in our tradition and that the System is only one of them. Others are the Pattern, Form, Domain, Meta-system etc. What we see is that the System Schema is just one among many and not predominant like we might have

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<sup>4</sup> See Stopford, John. *The Skillful Self: Liberalism, Culture, and the Politics of Skill*. Lanham, MD: Lexington Books, 2009 for non-representable skills

expected. In fact in our tradition the Form Schema was always predominant, and it is as an alternative to the Form Schema that the System Schema was introduced. But in the Twentieth Century two different schemas have battled it out for supremacy in Science, Structure (Pattern) and System. Structure because it is conducive to Reductionism and Analysis has generally won the day in the Disciplines. But now very few argue against holism as they have done in the past, and the Systems Schema has also found its adherents, but for Systems Engineering it is in fact a necessity. Some Systems Scientists like George Klir combined the pattern, form and system schemas to produce a Formal Structural Systems Theory which is very powerful as a way to look at the way these various Schemas interact with each other in specific domains. But until the actual development of General Schemas Theory and the positing of the S-prime hypothesis these efforts were not self-conscious. What we are doing in General Schemas Theory is looking for all the possible schemas to be used by Science, and that have been used by Science and we have made them a special subject of study that is not just trans-disciplinary but also trans-schematic. What are all the schemas, and how do they work together in our scientific understanding of experience which by the way is confirmed by our phenomenological experience as well in the lifeworld. Schemas suddenly also become a bridge back to the lifeworld for science as well as a bridge between different ways of looking at the same phenomena in any given discipline as well as across disciplines. Schemas Theory functions at the level of a change in the way we project the spatio-temporal world that makes science possible by setting up templates of understanding for phenomena to fill within the disciplines as we go about the business of science as human beings. In schemas theory we recognize the various points of view we take on phenomena by seeing the projection of the synthetic a priori in a phenomenologically agreeable way not just as a projection of a homogeneous plenum of objective spacetime as the background for all phenomena including the technological infrastructure we build. Instead Science and Engineering becomes a laboratory in which we look for schematic differences and we attempt to refute the S-prime hypothesis by finding gaps in what the schemas say are the building blocks of our world. So we are with Schemas Theory doing phenomenological science attempting to refute a hypothesis about the actual number of schemas that exist and their relation to mathematics.

But the key here is that schemas actually function at the spacetime a priori level and the concept of a general schema is in fact at the next level up which Friedman urges us to recognize which is the meta-framework level. We can understand this with an analogy from n-category theory. N-Category theory says that there are different meta-levels of category and at each level there is a different type of arrow, thus at the bottom level within a category there is an arrow which maps from objects to objects. But between categories there are functors, and these are like the individual schemas, but in order to actually see the differences between the functors we have to go up to the natural transformation<sup>5</sup> level which is a mapping between functors. Beyond this there are other levels called modifications and fluctuations but we will

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<sup>5</sup> Friedman uses this term "Natural Transformation"

not discuss these here<sup>6</sup>. What we need to discuss here is the relation of arrows, functors between categories, and natural transformations between categories of categories. Oddly it is at this third level that the most possible difference is generated, and that is what gives us the differences between the schemas as spacetime templates of understanding or pre-organizations of experience within which disclosure takes place. So Schemas Theory is at the level of a meta-framework which allows us to recognize the differences between the schemas at the functor level, which then allows us to bring different kinds of maps to bear within the categories at the arrow level between objects. Thus are articulation of the difference between the Schema as general concept and the specific schemas posited by the S-prime hypothesis exactly matches the difference Friedman makes between A priori principles of spacetime organization and the meta-framework that helps guide and orient in the change from one paradigm to another. Here the paradigm shift is itself reflexive because it is a paradigm shift that brings something from the meta-framework to bear on the a priori synthetic level of projection of spacetime across the disciplines both in Science and Engineering. Schemas Theory is a bridge between Science and Engineering at the meta-discipline level because it serves to unify Systems Science so it can be absorbed by Systems Engineering, but it is also a bridge back from the projection of the homogeneous plenum of objective spacetime toward the way that spacetime is apprehended in the lifeworld. And because of its reflexive nature as a meta-framework and a paradigm in itself we also get a profound ramification at the epistemological and ontological levels as well. On the Epistemological level we get the switch from the Kantian Episteme to the Meta-episteme. And at the ontological level we get the differentiation of the kinds and aspects of Being as well as the Principles of Peirce and Fuller as articulations of the way we understand the schemas. The schemas are basically at meta-dimension zero between the Standings and Aspects on the one hand, and the knowledge structures on the other hand that come from the analysis of background variables at any given schematic level.

So we can see that the Schema as a general concept uniting the specific schemas is at the meta-framework level but that the schemas themselves that are organized by the general concept are at the a priori synthetic level of the paradigm's action on the disciplines. The action on the disciplines is to make them self-conscious of the a priori schemas that they are projecting and to draw them in to the search for anomalies to the S-prime hypothesis which will cause General Schemas Theory as the new normal in science to progress. What we have drawn on to make this paradigm shift is Heidegger's critique of the present-at-hand as the only judge of experience which science recognizes. Similarly to how Systems Engineering has been blinded by seeing everything as a "System", so to Physics and the other hard sciences and Engineering has been blinded by seeing everything in terms of the "kosmos" schema and then as projected the plenum of Spacetime as the universal backdrop for all "interesting" phenomena. The problem is that the Kosmos schema is beyond our direct experience as a whole and this is one reason there is a

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<sup>6</sup> See Emergent Design dissertation of the author at <http://emergentdesign.net>

disconnect between Science and Lifeworld experience. Perhaps the objective reification of spacetime by the algebraic-geometry of Descartes ends up as the most primordial assumption of science, but still we see that science is not the only human project and science could not go on without the other human projects that we are engaged in and there are other kinds of knowledge associated with other aspects of human life within the world, there is also the ready-to-hand which we are engaged in creating as engineers as a side effect of creating present-at-hand technological infrastructures. But both the modes of being-in-the-world that sees these two kinds of Being is based on something more basic which is phronesis of praxis as our fundamental way of coming to terms with life and experiencing the facticity of life beyond Pure and Process Being. Continental Philosophy after Heidegger's Being and Time also identified Hyper and Wild as well as Ultra Being, so that there are actually several striations to the concept of Being that we must recognize. Human beings have to cope with these other kinds of Being as well as Pure and Process Being. These ontological structures that are derived from the application of Russell's theory of higher logical types to the concept of Being help us to understand that there is a fundamental change at the level of ontology that goes with the Schema paradigm shift as well as the change from in the Kantian Episteme to the Meta-episteme by which the present-at-hand is more precisely defined.

But following Friedman we can go further because he says that there are some principles that need to be applied to the paradigm shifts that occur given the three levels he has adumbrated. First the new paradigm contains the old as a limiting case. This is true of Schemas Theory where the System is contained as one among many schemas and thus the term System means something in the context with the other different schemas. Second he says that the new must evolve out of the old principles. And we see that this is the case with Schemas Theory because once we have this idea we can look back and see that the tradition was always full of different schemas, and that when we look around at our work and the world in which we live we can see we are constantly dealing with a lot of schemas already, we just did not think about the differences between them clearly before as we lumped them together all under the rubric of the system schema. But clearly there are patterns and forms and other schemas very different from systems, and the proof of this is the battle between systems theory and form and structure as different schemas during the twentieth century which vied for predominance in science. Third, the new meta-frameworks productively interact with the old meta-framework to give natural, reasonable, and responsible change within science. And this means that there is operative a dynamic a priori that is approaching a limit just as Cassirer suggested. It means that the meta-framework that produces the homogeneous plenum of objective spacetime as the right answer prior to Schemas Theory must be elucidated by the meta-framework instituted by Heidegger that calls into question the totalitarian view that there is only one schema for all of spacetime which neither Newton, Kant nor Einstein questioned. And Heidegger questions this in Being and Time based on his understanding that in our tradition we used to have other kinds of recognized knowledge than just scientific knowledge and we need to return to that diversity in kinds of knowledge giving each their due. Science departed from

the Aristotelian view of the physis fundamentally because of Descartes discovery of the duality of geometry and algebra which allowed us to project the present-at-hand backdrop to all physical processes. This backdrop has been reinterpreted during each of the breakthroughs into new paradigms in science. Now we have Systems Engineering coming along which must create technological infrastructures for human beings to work within and dwell within. And when we search for its foundations what we find is Schemas Theory, i.e. that we have to go up a level from the System to a new level of abstraction when thinking about spacetime and the way we understand how things appear within spacetime such that they are intelligible with different organizations at different phenomenological scopes. Thus from an unexpected source we find that the projection of a homogenous plenum no longer really works for how we see our technological infrastructure as purely present-at-hand with human system integration added on as an afterthought about the users. Rather as human beings that are creating these technological infrastructures to offer affordances to other human beings and perhaps ourselves as well we realize that we need to return to what we experience in our lifeworld as a priori synthetic projections of organization in order to understand the systems we design and build. And this is prompted by the pressure to build larger and more encompassing technological infrastructure elements all the time of even greater complexity. In other words we cannot afford to separate ourselves from our projections any longer with the fantasy that there is a noumenal homogeneous spacetime that we never experience but which is objective and which then isolates us as subjects. Rather we need all our resources to be able to design and build these technological infrastructures and that means our human resources which get expressed in all the ways we schematize or pre-organize our experience. Suddenly what Systems Engineering needs as a discipline to face the pressures of ever more complex technological infrastructure projects dovetails with what Heidegger's Critique offers, i.e. a path back to the lifeworld by realizing that there are many different kinds of knowledge beyond epistemic knowledge that human beings have that go beyond the knowledge of science and engineering of technological infrastructures that offer affordances. Through posting the paradigm shift of Schemas Theory we open up the other types of knowledge that make up the lifeworld described as the core of the worldview by Plato and Aristotle. We open up the various meta-levels of Being, but also we open up the Kantian Episteme into the Meta-episteme. And all this we gain just by moving to a higher level of abstraction beyond the system and recognizing all the schemas working together that we have developed within our tradition and use every day which have been obscured by our over emphasis on the System Schema and associated blindness to the Meta-system or OpenScape schema.

Friedman goes on to identify that the key element of these paradigm shifts in science that are approaching a limit is that there are coordinating principles that are developed that connect mathematics with empirical science. And sure enough the Schemas in their relation to the Philosophical Principles of Peirce and Fuller are just such a set of coordinating principles. The math is dimensionality in this instance and what the math does is it allows us to produce the difference between the schemas by a simple rule that is part of the S-prime hypothesis which is that there are two



schemas per dimension and two dimensions per schema. When you are given a list of ten schemas that takes us from the negative first dimension to the ninth dimension, just short of where String Theory as well as M and F Theories commence. String theories are not schematized. There is no natural organization of our templates of understanding that encompass them so they are math without bridging to the lifeworld. Not only can't we test them we can't understand them as we understand other things in the world either. The coordinating principle that we are applying is that spacetime has to be phenomenologically apparent in its organization by us as human beings. Schemas are the way we have always projected that organization prior to experience itself, but we have always ignored that in the metaphysical era because in that era the only concern was about the spacetime chora<sup>7</sup> as Kosmos within which the physis develops and evolves through poiesis. Here we turn the tables on this and say that we are rooting our experience of spacetime in the lifeworld itself and how spacetime is disclosed to us in our experience. Suddenly we have multiple projected synthetic a priori with different organizations at different scopes that we see, and what we see is that we have always had them and they have been developed down through the ages in our tradition as various schemas. Umberto Eco tells this story of the development of the idea of the Schema in Kant and the Platypus, and in it he identifies the 'Mathematical and Geometrical' schemas as the most basic type. With the S-prime hypothesis we merely name them and give the rule that connects them to the mathematics of dimension. That hypothesis is given just to kick off General Schemas Theory as a trans-disciplinary and trans-schematic domain of study that encompasses all the other sciences and engineering disciplines as a meta-meta-discipline above both Systems Science and Systems Engineering that are meta-disciplines. Bridging that divide which Systems Engineering was blissfully ignorant of until recently forces us to a higher meta-level in order to make the bridge happen and this gives us our unifying principle to apply to the Systems Science theories in order to make them available as knowledge to Systems Engineers to help them with their practice in creating technological infrastructures that contain both systems and meta-systems as well as elements related to all the other schemas as well.

Thus in every way Schemas Theory fulfills the criteria that Michael Friedman would impose on our Paradigm Change from those changes he witnesses in the history of Science, which is at the same time a history of Engineering breakthroughs that have enabled science. But actually our positing of Schemas Theory as a possible paradigm shift not just for Systems Engineering but for other disciplines as well because no other discipline has yet spawned anything like Schemas Theory so it is a unique emergent event within Academia coming from Industry but yet with an unknown possible implicit impact on many disciplines. It goes beyond what is normally expected from a paradigm shift because this particular shift ramifies not just to the Epistemological and Ontological levels but to the level of Existence and Absolutes as well and ultimately leads us to question the metaphysical eras presumptions that separate out the physis from the logos through the nomos. All of these various

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<sup>7</sup> <http://en.wikipedia.org/wiki/Kh%C3%B4ra>

levels of impact will be explored in this series of working papers. Schemas Theory is well established in the sense that it was presented in 2004 to the CSER conference in a plenary and multiple papers have been written exploring its implications culminating in my Ph.D. Dissertation in 2009 on Emergent Design (<http://emergentdesign.net>).

In this introduction we merely wish to explore further how well this proposed paradigm shift compares with the theory of Philosophers of Science like Michael Friedman. And we can see that it compares favorably, and even articulates further than Friedman is prepared to go in terms of producing ramified changes up the ladder of the various levels of scopes of possible emergence in the tradition. When we take all this together it is strange that the place where this paradigm shift is instituted is in Systems Engineering, not the most radical of disciplines. I think this may be because Systems Engineering is representing the way that the physus comes back toward the logos at the higher meta-level of abstraction. When you think about it we develop science which objectifies nature, and then we develop technology through engineering that subject's nature. As Bolos of Mendes said roughly that that fist nature produces nature, then nature controls nature, but eventually nature enjoys nature<sup>8</sup>. But then this does not take into account that we ourselves are nature, and thus when we add the correspondence principle that we should experience spacetime as a synthetic a priori then it falls out that this experience is not of a homogeneous plenum but of a set of differences that make a difference to us in the way we render spacetime intelligible in the lifeworld as is disclosed in our experience of our world. And that is the key to understanding what we need to actually help us build the technological infrastructure better and understand science more deeply.

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<sup>8</sup> Or "Nature overcomes Nature, Nature rejoices in Nature, Nature contains Nature." The Turba Philosophorum Forty-Fifth Dictum