MODELING THE ROLE OF BOUNDARY SPANNERS-IN-PRACTICE IN THE NONDETERMINISTIC MODEL OF ENGINEERING DESIGN ACTIVITY

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Boundary spanners-in-practice (BSIPs) are individuals who inhabit more than one social world and bring overlapping place perspectives to bear on the function(s) performed within and across each world. Different from nominated boundary spanners, they are practitioners responsible for the 'translation' of each small world's perspectives thereby increasing collaboration effectiveness to permit the small worlds to work synergistically. The literature on knowledge management (KM) has emphasized the organizational importance of individuals performing boundary spanning roles by resolving cross-cultural and cross-organizational knowledge system conflicts helping teams pursue common goals through the creation of "joint fields" - a third dimension that is co-jointly developed between the two fields or *dimensions* that the boundary spanner works to bridge.

The Copeland and O'Connor nondeterministic model of engineering design activity was utilized as the foundation to develop models of communication mechanics and dynamics when multiple simultaneous interactions of the single nondeterministic user model, the BSIP and two subject matter experts (SMEs), engage during design activity in the problem-solving space. The problem-solving space defines the path through the volumes of plausible answers or 'solution spaces' that will satisfice the problem presented to the BSIP and SMEs.

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Further model refinement was performed to represent expertise seeking behaviors and the physical and mental models constructed by boundary spanners-in-practice during knowledge domain mapping. This was performed by mapping the three levels of communication complexity (transfer, translation and transformation) to each knowledge boundary (syntactic, semantic and pragmatic) that must be bridged during knowledge domain mapping.

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PREFACE

There is a book in my collection. Actually, it isn't ever in my collection because it is typically within my reach or a few steps of my workstation, wherever that may be. It has been underlined and high-lighted with at least four different colors of ink, contains penciled notes, the cover is showing wear, and the pages have been unceremoniously dog-eared when I have lost bookmarks in my travels. And it has travelled with me - to every continent except South America, Antarctica and the island of Greenland, as I have yet to be assigned to projects there.

It's not that I haven't tried to leave it safely on a shelf; I have. But so many times I need to step into a role, execute a task, reengineer a process to support a team – and I reach for that book so I can understand the context and approximate the place in the problem-solving space in which the team(s) are at that point in time.

I never expected *Hunting and Gathering on the Information Savanna* (O'Connor, Copeland, & Kearns, 2003) to become one of those essentials, those must-haves that you cannot leave without. Like glasses. Or your phone. But there it is. It has become one of my tools of the trade.

I am a 'hunter and gatherer' - but I didn't use those terms in the context of 'me', information professional, until recently. I work in the problem-solving space with other professionals that engineer solutions to significant problems. And I understand the value of conversation especially within the context of knowledge management and knowledge transfer activities.

The conversations presented as case stories in *Hunting and Gathering* take place amongst the authors and between an author and a particular participant and have

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been presented in such a way as to 'invite participation' of the reader and stimulate questions. Chapters five and six present a case story that distills the work of various authors that studied engineering design work describing it as intrinsically human and "another way of talking of hunting and gathering" (O'Connor & Copeland, 2003, p. 95). Chapter five concludes by presenting a model that "fram[es]…and generat[es] inferences about engineering design activity as a human information-seeking activity" (O'Connor & Copeland, 2003, p. 95).

It's that model that I just couldn't get out of my head.

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INTRODUCTION AND CONTEXT

In *Public Knowledge, Private Ignorance* (Wilson, 1977), Patrick G. Wilson identified a gap in library service offerings. Beyond providing bibliographic assistance and answering questions posed by library users, Wilson suggested that a new service offering should be developed, describing it as "a functional information service…that would discover the state of public knowledge as it bears on particular problems" (Wilson, 1977, p. 108). He was quick to acknowledge that this idea was not original but that it had been presented previously in 1924 by William S. Learned.

Wilson stated that this functional information service needed to "be concerned with the irregular and unpredictable information needs of individuals…[and] to increase the accessibility of public knowledge to individuals" (Wilson, 1977, p. 113). It is most interesting to note that he continued this discussion focusing on ways in which *knowledge* could be made available to individuals including a specific reference that this *knowledge* to which he refers does *not* include documents. Wilson stated that opportunities could be offered to individuals to acquire the knowledge directly or that opportunities could be offered to individuals to secure help from those who have already acquired it. However, these two paths led to two different outcomes. The first would take an individual down the path to direct knowledge acquisition – leaving the individual to apply the knowledge gained to a particular problem as they chose. The second would take the individual to advisors who were not only knowledgeable but could apply their knowledge directly to the individual's particular problem, placing context around the knowledge proffered and recommending courses of action. Wilson assigned the title "information doctor" to this new breed of information professional whose job was to act

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as surveyor of knowledge within a group responsible for aggregation and cultivation of a particular knowledge domain. For Wilson, this meant that an information doctor would be required for every field in which this advisory service was to be offered.

Wilson's idea of the role of "information doctor" has been embraced by many organizations. This idea that information doctors are surveyors of knowledge within a particular knowledge domain aligns with the notion of the Subject Matter Expert (SME), a designation used formally or informally in numerous industries today. Both Dreyfus and Wilson address multiple components of expertise. Dreyfus examined expertise first from the vantage point of learning a skill by following rules until the performance becomes automatic as the physical body has "picked up the muscular gestalt which gives our behavior a new flexibility and smoothness (Dreyfus, 1979, p. 249). Dreyfus also examined expertise as "expert judgment" which he stated was acquired through internship and the use of examples. His fascination with artificial intelligence and the limits imposed by following rules such as those in computer programs drove him towards "developing new, flexible, complex data types which will allow the representation of background knowledge in large, more structured units" (Dreyfus, 1994, p. 34). Wilson not only addressed expertise within the role of "information doctor" but also examined expertise from the point of cognitive authority. Wilson stated, "[c]ognitive authorities are authorities on something – e.g., insects or Buddhist logic" (Wilson, 1991, p. 260). But cognitive authority is also a matter of social perception and recognition, meaning that if no one recognizes that you have special knowledge on a particular topic, you are not an authority. In addition, cognitive authority is associated with scope – cognitive authority may be narrow or broad. A person's cognitive authority

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may be narrow if it is only known within the membership of a particular small world or it may be broad and far-reaching if the person is the recognized global expert (Wilson, 1983).

And that these SMEs are clearly associated within a group responsible for a particular knowledge domain introduces Chatman's work on "small worlds" and "insiders and outsiders" (Chatman, 1996, 1998). According to Chatman, "…a small world has a specific context that serves a particular population to permit its members to conduct their business in a routine, expected manner" (Pendleton & Chatman, 1998, quoted in Burnett, Besant & Chatman, 2001, p. 536). But Wilson expected his "information doctors", or SMEs, to advise in areas that were exceptional, areas which required new investigation that would add to the corpus of knowledge in a particular domain. He further posited that if the SMEs were only required to advise on routine matters, the advisory service could then be reduced to that of a functional information service with advisors dependent on collections of research documents rather than on their mastery of tacit knowledge domains.

Wilson did not expect these information doctors to support diffusion of knowledge to the public at large but rather support problem-solving and decision-making for those individuals requiring context-specific advice and implementation guidance which the SME's experience and expertise determined to be most applicable. Wilson stated "The mass media, the specialized media, personal "change agents," and the educational system are all better agents of diffusion" (Wilson, 1977, p. 112). These information doctors, or SMEs, hold a special place within the group or "small world" of which they are a part as they "own" expertise within a particular knowledge domain.

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The goal of this research is to further inform and refine the Copeland and O'Connor nondeterministic model of engineering design activity, adapted from Copeland (O'Connor, Copeland, & Kearns, 2003, p. 141), bringing the foundations of information philosophy (Wilson, 1977, 1983; Chatman, 1991, 1998) to the conduct of complex knowledge work. This model resulted from examination by Copeland and O'Connor of engineering design activity; however, it is important to note that the model was developed to explain design activity at the level of a single nondeterministic user.

This research will address the following questions:

- How can the model be further informed to address the mechanics and dynamics in which boundary spanners-in-practice (BSIP) engage with one or multiple small world Subject Matter Experts (SMEs)?
    - How does the model change in aggregate when multiple simultaneous interactions of the single nondeterministic user model engage during design activity?
    - How can the model represent expertise seeking behaviors and the physical and mental models constructed by boundary spanners during knowledge domain mapping?

Integral to this research project, comments and conversation offering context and validation will be inserted occasionally from the research participants, each of whom have been assigned a non-identifying descriptor Boundary Spanner-in-Practice (BSIP) numbered 1 through 4. As well, BSIP1 introduces the notion of the 'problem-solving space' (PSS) which Copeland (1997) terms the 'solution space.' "Decision and systems theorists sometimes refer to these volumes of plausible answers as 'solution spaces,'

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and problem-solving, defining paths through these volumes, as “searching” solution space (Hapgood, 1993, p. 7). The problem solving space described by BSIP1 is aligned with these notions; it is envisioned as a space in which human activity is directed to develop an array or range of solutions to a complex problem. The boundaries are somewhat amorphous and vary in permeability to various resources allowing them to flow into and out of the space.

BSIP1 related a case story about an engineer with no formal training that exemplified Wilson's information doctor:

> *BSIP1: I had an engineer that never went to school, never got an engineering degree. All his engineering capability and understanding came from just having done the work; some of it doesn’t have to be expertise but rather common sense and how you approach the situation. And yet he was able to, without having the equations or technical expertise, perform engineering functions, and sometimes even better than an actual engineer just by having had the experience or the conceptual.*
>
> *We were talking about cutting wood. Over time, people have learned how to interact with the wood, how to make certain cuts, how to make it give them the maximum strength for bonding. If you took somebody that had never worked with wood, and didn’t appreciate the quality of the wood or the grain, they may do it differently and it would compromise the bond because the wood going cross-grain is not going to be as strong as the when the grain is going the same direction. So some of it, you do the same procedures, the same cuts, the same*

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processes, but it has to be brought more into a space where you understand all the variables that you need to control.

BSIP4: So let's relate this back to this engineer who hadn't gone through formal training, the way you have and the way most engineers today are trained. How would they be able to represent variables if they hadn't learned the symbology associated with engineering? Would they learn this through on-the-job training as a journeyman apprentice? Help me understand - I'm curious about this person because, as you can imagine, that's totally beyond my context. I don't know of anyone that's in the engineering space that has come up this way. How would a person that doesn't have the same set of knowledge bases that someone that would have gone through, say, the formal education process - how would they be developing the sorts of expected knowledge bases that a person in that capacity would have or should have?

BSIP1: Mathematics doesn't necessarily need to be there for an engineer. Math is around us at all points – even if you are baking a cake, there still is a point at which you do a fixed measurement of some sort and some of those are fairly physical. He was aware of those. A barrel is a barrel, an atom is an atom, and electrical current is a current. There were certain measurements that he became aware of just by having been there, involved in the process. How you assemble all that knowledge together to perform an engineering task – that's the part that he was never taught and became innate for him. Some of it was

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probably trial by error-type scenarios and things did or didn't work and that became part of his knowledge base. The more complex things became, the more he had to pull from his line of experiences that build up to that type of thing. And there were certain things that he was not going to be able to accomplish. He probably had a limit because of not having formal training but a lot of the more basic stuff he could do as well as any other engineer.

BSIP4: So, he had to be extremely bright if he had learned as much about engineering as he had without typical standard formal higher education-type training. So would you say that he was certainly capable of learning the various mathematical equations? Would you say that he was proficient in both the mathematical symbology and the engineering symbology? Or were there gaps?

BSIP1: There were gaps but he had filled some of the gaps that he had had in the past. If someone had taken the time to explain to him, "here are some equations or here are some processes," he was capable of picking those processes up.

BSIP4: So…We've got you, the BSIP, and a SME (SME #1), truly an expert in his own right because of his innate understanding of engineering and, because of his experience, having done any number of engineering activities that he had been successful at whether there was math or other symbology that he needed to know or not, he was a successful engineer. He brought expertise to

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bear in the PSS. How would you have worked with him with, say, another SME (SME #2) to solve a problem which he (SME #1) might have been unable to solve by himself and, perhaps, would have been difficult for a trained engineer (SME #2, with formal higher education training and experiential learning as an engineer working in the field)? How would you have worked with them - knowing you, as BSIP, were bringing these two SMEs, with very dissimilar expertise/experiential bases, together to work as a threesome on a difficult problem…?

BSIP1: Because somebody has been in a trained environment doesn't necessarily make them a better engineer.

BSIP4: That's true; the piece that's very critical in an engineering capacity is the ability to apply common sense.

BSIP1: The one brought experience base and application base. The other one may not have had similar application base but may have had the technical base to solve some of the more complex or the less aware parts of the problem that needed to be solved. The practical engineer may have taken a lesser success or accomplishment….

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BSIP4: And that just the concept of "satisficing" again; it doesn't have to be perfect. All it has to do is work. (BSIP1 personal communication transcript of video recording November 17, 2012).

The engineer about which BSIP1 spoke was capable of supporting problem-solving and decision-making for others requiring context-specific advice and implementation guidance which the engineer's/SME's experience and expertise determined to be most applicable. Clearly, this SME held a special place within the group or "small world" of which they were a part as they "owned" expertise within a particular knowledge domain.

Boundaries and Small Worlds

In the article, "Team boundary issues across multiple global firms", Espinosa, Cummings, Wilson, and Pearce (2003) identify five types of boundaries they encountered in their field research:

- Geographical boundaries are present in a team when some of its members are separated by distance (Espinosa et al., 2003, p. 161).
- Functional boundaries are present when more than one area of functional expertise is represented on a team, such as marketing, engineering and manufacturing (Ancona & Caldwell, 1992; Denison, Hart, & Kahn, 1996; Eisenhardt & Tabrizi, 1995; Espinosa et al., 2003, p. 165).
- Temporal boundaries are present in a team when some of its members are separated by time because of differences in working hours, time zones, or

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working rhythms that reduce the time available for same time (i.e., synchronous) interaction (Espinosa et al., 2003, p. 170).

- Identity boundaries are present when some of the members of a team are not fully dedicated to the team, either because they are working on multiple projects with multiple teams or because their teams are nested within larger teams (Espinosa et al., 2003, p. 174). It is not unusual for team members to be involved in more than one project, team, or organizational unit at a time making it difficult for members to define their identity at any point in time.
- Organizational boundaries are present in a team when its members belong to more than one organization (Espinosa et al., 2003, p. 178). As interorganizational forms evolve including outsourcing, joint ventures, partnerships, and alliances, differences in organizational affiliations can reduce shared understanding of context and decrease a team's ability to develop a common identity.

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Table 1

Issues Global Teams Face Grouped by Boundary

Boundary	Boundary Issues
Geographic (i.e., some members are separated by geographic distance)	Geographic distance can confound other variables: familiarity, media, expertise, tenure, organizational boundaries Geographic distance may not be exogenous Distance is not always a static phenomenon "Meaning" of distance Nonlinear nature of distance Confounding potential of "external" distances
Functional (i.e., more than one area of functional expertise is represented in the team)	Functional affiliations may change the meaning of other boundaries Differences between perceived and actual functional representation Function confounds other variables: expectations, reputation, power, authority Function confounds other boundaries: geographic distance and organizational boundaries Function interacts with other boundaries
Temporal (i.e., some members are separated by time – differences in working hours or time zones)	The asynchronous nature of a task may be moderated by geographic distance Geographic distance and temporal boundaries are more likely to covary when different time zones are involved Task interdependencies and communication media are often inherently tied to temporal boundaries Temporal boundaries can be confounded with national-cultural boundaries Patterning of temporal boundaries Temporal boundaries covary with organizational boundaries Confounding of differences in time zones
Identity (i.e., some members are not fully dedicated to their teams; they also work with other teams)	Multiple memberships affects identify/affiliation Involvement in multiple projects, events, groups or work processes impacts identification Time commitment differs across members and teams Membership may be dynamic thus making it difficult to define Identify is a powerful influence on behavior and does not always covary with time spent working on team activities Identity is dynamic and can shift over time
Organizational (i.e., members belong to more than one organization)	Organizational practices confound other boundaries such as distance Interorganizational groups and internal groups have distinct group processes Some teams include members from external organizations Members exist in two contexts Organizational affiliation does not exert a uniform influence Variation in number and patterning of organizations represented Organizational boundaries interact with other boundaries

Note. Adapted from "Team boundary issues across multiple global firms" by J. A. Espinosa, J. N. Cummings, J. M. Wilson, and B. M. Pearce, 2003, *Journal of Management Information Systems, 19*(4), p. 162-180. Copyright 2003 by M. E. Sharpe, Inc.

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The exposition of boundaries and their impact on teams or, more broadly, on groups, has been purposeful, focusing the attention of the reader on the *white space between each team/group*. Present day social network analysis stems from the sociometric analysts who worked on the measurement of interpersonal relations of small groups and produced a number of technical advances in graph theory methods. Jacob Moreno described his 1930's innovation, the sociogram, as an *invention* and it is this that marks the beginning of sociometry. Moreno is widely known as the founder of the field of sociometry which he described as "the sociometric revision of the scientific method of the social sciences that will gradually make such a thing as a science of society possible" (Moreno, 1960, p. *x*). Sociograms offered a way to represent and measure interpersonal relationships within small groups. The diagrams were analogous to those used in spatial geometry; nodes were used to represent individuals and the representative social relationships between individuals were represented as lines. Sociograms offered researchers a way to visualize definite, discernable interpersonal structures within a group. This is such an established idea now that it is hard to imagine how innovative sociograms appeared in the 1930s. This was the first time that researchers could visualize information flow between individuals and how particular individuals influenced others.

Kurt Lewin's early studies on group behavior suggested that group behavior was "determined by the field of social forces in which the group was located" (Lewin, 1936, quoted in Scott, 1991, p. 11). He further argued that social groups exist in a field or social space that comprises the group together with its surrounding environment. Group members actively construct meaning on the basis of their perceptions and contextual

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experiences. While Lewin's work predates Chatman's by more than fifty years, the similarities to Chatman's concept of "small worlds" is striking (Chatman, 1996; Pendleton & Chatman, 1998).

Lewin's topological approach to sociograms describes a field model comprised of points (individuals or "actors") connected by paths representing individual's goals or interactions. For Lewin, the field model described causal and interactional interdependencies in the social configuration. He further observed that the paths that run between points tie them together dividing the field into a number of regions. Regions were defined by paths running with but not between regions; the significance of the *absence of paths* would lead to future studies of boundary objects and boundary spanners (Star & Griesemer, 1989; Di Marco, Taylor, & Alin, 2010). Lastly, Lewin foreshadows two additional concepts in Chatman's model, social norms in a small world and her notion of worldview. "The opportunities that individuals have to move about in their social world are determined by the boundaries between the different regions of the field in which they are located. The constraints imposed by these boundaries are the 'forces' that determine group behavior. The total social field, therefore, is a field of forces acting on group members and shaping their actions and experiences" (Scott, 1991, p. 11).

In 1956, Cartwright together with Harary, a mathematician, built on Lewin's work, pioneering the application of graph theory to group behavior. Graph theory had originally been formulated in Germany in the 1930s by König but had little impact until 1950 when the book was republished in the United States. The mathematical ideas presented provided a crucial breakthrough in the theory of group dynamics as it moved

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the concept of cognitive balance in individual minds to that of interpersonal balance in social groups. This offered researchers an opportunity to build models visualizing the systematic interdependence between attitudes held by different individuals within a group. In 1956, Cartwright and Harary generalized this claim by developing a theoretical framework outlining the basic idea of representing groups as collections of points connected by lines with the resulting sociogram representing the network of actual interpersonal relations among group members. These relationships could be analyzed using the mathematical ideas of graph theory describing “positive” or “negative” relations and arrow heads to represent the ‘direction’ of the relationship. The construction of ‘signed’ and ‘directed’ graphs allowed Cartwright and Harary to analyze group structure from the standpoint of each of the group’s members simultaneously rather than from the standpoint of a particular member of the group as the focus.

Concurrently, work at Harvard University investigating ‘informal relations’ in large-scale systems yielded empirical evidence that these systems did, in fact, contain cohesive sub-groupings. Mayo and Warner undertook two social investigation projects, The Hawthorne electrical factory in Chicago and a study of a New England community dubbed “Yankee City’.

The Yankee City study afforded Warner the opportunity to study 'cliques', a particular configuration of informal interpersonal relations in the city of Newburyport. Based on the “Yankee City’ study, Warner and his associates claimed that membership in cliques was second in importance only to that of “family” in placing people in society. It was observed that any person could be a member of several different cliques and “such overlapping in clique membership spread out into a network of interrelations

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which integrate[d] almost the entire population of a community in a single vast system of clique relations" (Warner & Lunt, 1941, p. 111 quoted in Scott, 1991, p. 21). This is one of the earliest, if not the earliest, uses of network terminology to describe the structuring of a whole society into sub-groups.

The importance of the Hawthorne studies in the development of social network analysis stems from the use of sociograms to report on group structure. Sociograms were used to illustrate the structure of informal relations within the work group as opposed to the formal organization that was depicted in the managerial organization chart. The Hawthorne study was the first major investigation to employ sociograms to describe actual relations observed in multiple situations. What is interesting to note about the Hawthorne study is that there is no discussion of Moreno's work included in it.

In the late 1940's, Homans undertook to synthesize both the experimental work of the social psychologists and the observational work of the sociologists and anthropologists. His theoretical synthesis centered on the idea that human activities brought people into interaction with each other; these interactions varied in 'frequency', duration', and 'direction', forming the basis for development of 'sentiments' among people. Homans saw Moreno's sociometry as able to provide a methodological framework for applying this theory to particular social situations. Homans started by reanalyzing Warner's 'Old City' matrix data (Homans, 1951). He presented the first published statements on the method of 'matrix re-arrangement' in social network analysis with his re-representation of the data subsequently dubbed 'block modeling'.

At Manchester University, a small group of anthropologists, John Barnes, Clyde Mitchell and Elizabeth Bott were influenced by British social anthropologist Radcliffe-

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Browne, Max Gluckman, and Parsonian structural functionalism. They sought to develop Radcliffe-Brown's concepts of integration and cohesion in a novel way focusing instead on conflict and change. This integrated well with Gluckman's interest in complex African societies and how role conflict and power played in both the maintenance and transformation of social structure. Parsons' structural functionalism (Parsons, 1937, 1951) required actions to be interpreted as expressions of internalized value orientations. The work of the Manchester anthropologists reflected these three perspectives; their work emphasized "seeing structures as networks of relations combining the formal techniques of network analysis with substantive sociological concepts" (Scott, 1991, p. 27).

Initially, the Manchester anthropologists employed the idea of a social network in a metaphorical sense but in the early 1950s, Barnes began to apply the idea in a more rigorous and analytical way. His work had considerable influence on Bott and the two began to investigate studies previously undertaken in the sociometric tradition. The papers they produced (Barnes, 1954; Bott, 1955, 1956) were received favorably by social anthropologists as the notion of a social network helped meet a need providing concepts to use in understanding complex societies.

In 1957, Siegfried Nadel espoused the social network approach through a series of lectures and a book (Nadel, 1957) on social structure. Nadel defined structure as "the articulation or arrangement of elements to form a whole. By separating the forms of relations from their contents…the general features of structures can be described and…investigated through a comparative method" (Scott, 1991, p. 29). Nadel advocated construction of formal models and a mathematical approach to structure

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articulating definitions for social structure, network, and role. Ultimately, his text became the charter statement for the developing program.

From tasks outlined by Nadel in his book, Clyde Mitchell undertook to lay the foundation for a systematic framework for social network analysis. Based upon his review of the original mathematics of graph theory which had emerged from early sociometric work, he reformulated the ideas to create a distinctly sociological framework (Mitchell, 1969). Mitchell codified the interpersonal relations analyzed in social network analysis into that of the 'personal order'. "The personal order is the pattern of personal links individuals have with a set of people and the links these people have in turn among themselves" (Mitchell, 1969, p. 10 quoted in Scott, 1991, p. 30). These patterns defined the sphere of network analysis stemming from two different types of interaction. The first, communication, "involves the transfer of information between individuals, the establishment of social norms, and the creation of a degree of consensus….[The second is] instrumental or purposive…action, which involves the transfer of material goods and services between people" (Mitchell, 1969, p. 36-39 quoted in Scott, 1991, p. 30).

From Mitchell came the ability to analyze ego-centered networks (social relations anchored around a central person), global features of networks in relation to aspects of social activity (political ties, kinship, friendship, work relations, etc.) as well as the quality of relations (reciprocity, intensity, durability) in interpersonal networks. He also added a set of concepts derived by translating graph theory into sociological language to help describe the texture or topology of social networks of which "density" and "reachability" are examples.

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A breakthrough for social network analysis occurred at Harvard University as a result of two key mathematical breakthroughs. The first was the development of algebraic models of groups using set theory to model kinship and other relations which led to a reconsideration of the early work in graph theory and the concept of 'role' in social structure. The second innovation was the development of multidimensional scaling, a scaling technique for translating relationships into social 'distances' and for mapping them in a social space.

Lewin's research, which foreshadowed Chatman's by more than fifty years, focused on group behavior; he argued that group members actively construct meaning on the basis of their perceptions and contextual experiences. Chatman's research refined the concept of "group behavior" focusing on what she termed "small worlds" and accompanying behavioral consequences for members of multiple small worlds. According to Chatman, "…a small world has a specific context that serves a particular population to permit its members to conduct their business in a routine, expected manner" (Pendleton & Chatman, 1998, quoted in Burnett et al., 2001, p. 536). Within small worlds, information behaviors ranging from information seeking through the continuum of information avoidance can be viewed as normative helping its membership define itself within the context of its particular small world as well as to understand its place within the larger world view.

Chatman's Theory of Normative Behavior incorporates four concepts: "(1) social norms; (2) worldview; (3) social types; and (4) information behavior" (Burnett et al., 2001, p. 537). The first concept, social norms, plays a significant role in holding the small world together by identifying acceptable standards and codes of behavior, helping

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to maintain a sense of order and balance, as well as by setting boundaries which most of the membership are disinclined to cross.

Chatman's second concept, worldview, "is a collective perception held in common by members of a social world regarding those things deemed important or trivial" (Burnett et al., 2001, p. 537). This collective approach to overall importance of things whether it be objects or information behavior (e.g., sharing, hoarding, active seeking, avoidance, etc.) as well as social standing (social types) figures heavily in the information flow model for the small world.

Chatman's third concept, social types, pertains to how a person or persons are classified within the social world. These social types not only classify persons but serve to increase and decrease information flow. Social norms require increased information flow amongst the membership of the small world in which the person is a member as part of the required tasks members must perform to execute daily business activities. But information flow is limited amongst peers that do not occupy the same small world based on their social type. While multiple objects are and must be shared, some volume of content is held separately by each small world.

Chatman identifies two social types, "insiders and outsiders", relative to small worlds. Chatman states: "The idea that things can only be understood by other insiders may explain why there are informational barriers between small worlds. One reason might be a doubt that insiders have regarding the ability of outsiders to understand their world" (Chatman, 1996, p. 194). An example of "insiders" may be Subject Matter Experts holding particular expertise or entrepreneurs whose creative minds invented and patented technologies for their employing organization. Insider and outsider social

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types typically receive different levels of access to information as insiders can claim privileges to certain areas of knowledge or expertise. These social types can impact information flow regionally, as well.

The behavioral consequences of the information flow model for the membership of small worlds are many. Active information seeking can consume multiple hours in any one day. Little browsing or foraging can be engaged in by a member of multiple small worlds unless full access is granted to the various resources and content exclusively held by each small world. This harkens back to Wilson's "information doctors" and is typically provided only to “insiders” of the small world or those that have the social type “Subject Matter Expert” ascribed to them. In some instances, such access may also be granted to “outsiders” whose cognitive authority or administrative authority provides access and permissions which do not stem from those social norms developed by and for the membership of the small world. More typically, selective exposure is offered by “insiders” of the small world to other members of the small world who occupy a lesser social role in the small world. With this comes decision-making for both pertinence and relevance of the resource for the person seeking information from the insider. Positive selective exposure presumes that the “insider” understands both the context and problem breadth so can better filter resources directing the member of the small world, who occupies a lesser social role typically because of less experience and expertise, to higher quality resources more pertinent to solving the problem at hand and ultimately saving time. Negative selective exposure is also exhibited by “insiders” who hoard resources exhibiting social types described as gatekeepers or bottlenecks. Such insiders can be motivated by power, cognitive or administrative authority, etc. These

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insiders serve to increase the information poverty of the small world's membership increasing rather than decreasing the overall knowledge gap within the small world membership.

Carlile (2004) developed an integrative framework for managing knowledge across boundaries. He describes three progressively complex boundaries – syntactic, semantic and pragmatic (Shannon & Weaver, 1949) – and three progressively complex processes – transfer, translation and transformation.

The relative complexity of a boundary is defined based on three properties of knowledge: difference, dependence and novelty. Difference in knowledge refers to a difference in the amount of knowledge accumulated, the novice-expert distinction and/or the difference in the amount of domain-specific knowledge aggregated. As differences in the amount or type of domain-specific knowledge increase between actors, the communication effort required to share and assess each other's domain-specific knowledge increases. Dependence is the condition where two entities must take each other into account in order to meet their goals. As the number of dependencies increase between actors, the complexity and amount of effort required to share and assess knowledge at a boundary also increases. Carlile utilizes the term "novelty' rather than "uncertainty" deliberately stating, "Uncertainty is an external characterization…not [all is] known in a given environment, whereas novelty…underscores the participatory and relational nature of what an actor needs to share and to assess when all is not known" (Carlile, 2004, p. 557). As novelty increases, the amount of communication effort required to adequately share and assess knowledge also increases.

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Carlile then scales the relatively complexity at a boundary using Shannon and Weaver's (1949) three levels of communication: syntactic, semantic and pragmatic. While these three terms focus on the effectiveness of sharing and assessing knowledge across boundaries, they also broaden the concern from just the structure, meaning, and use of language to Shannon and Weaver's practical concerns about what is required for effective communication across domains.

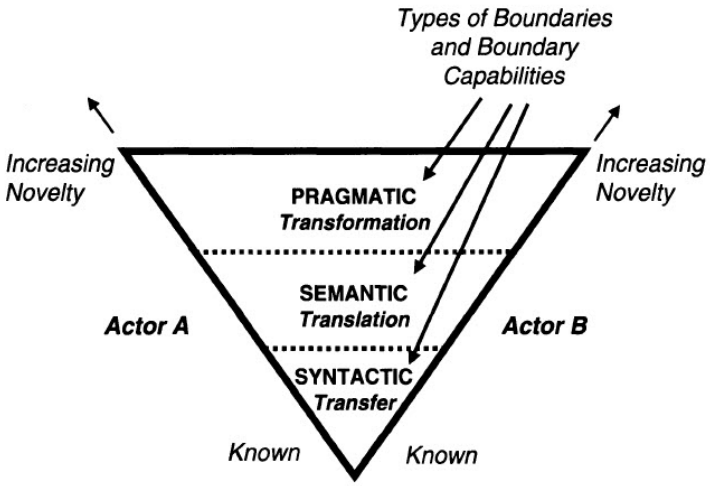

Figure 1. An integrated/3-T framework for managing knowledge across boundaries. Adapted from "Transferring, translating, and transforming: an integrative framework for managing knowledge across boundaries," by P. R. Carlile, 2004, Organization Science, (15)5, p. 558. Copyright 2004 by INFORMS.

At a syntactic or information processing boundary, knowledge processing or transfer occurs. This requires stable conditions and a common vocabulary to begin the process of developing a common knowledge base. At a semantic or interpretive boundary, knowledge translation occurs. Knowledge translation must be initiated when novelty presents differences and dependencies that are either unclear or ambiguous. At a pragmatic or political boundary, knowledge transformation occurs. When novelty

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presents results to actors that have differences, the dependencies between the actors are not indifferent requiring negotiation and knowledge transformation to pursue common goals through the creation of “joint fields.” These pragmatic differences in team dynamics and knowledge processes have been framed as “creative abrasion” (Leonard-Barton, 1995) while recognizing the role that shared artifacts and methods play in the ability to negotiate actors’ interests and transform knowledge. At a pragmatic boundary, actors must be able to represent current and more novel forms of knowledge, understand their consequences, and transform their domain-specific knowledge accordingly. This transformed knowledge creates a joint field and is both valuable and determined to be of consequence given the novelty of the solution/problem-solving space.

The Problem Solving Space

In the Copeland and O’Connor nondeterministic model of engineering design activity, the problem-solving space is referred to as the solution space. Taylor refers to it as the “negotiating space…[t]he dynamics of this space in a very real sense define the time, effort, initiative and even dollars” a user or client expends in actively seeking or receiving information, and where choices are made based on the criteria derived, consciously or unconsciously, based on the problem (MacMullin & Taylor, 1984, p. 94). According to MacMullin and Taylor, there is a distinct difference between what information is contained in the problem and what information is contained in the question. “A problem is a compression of the user situation with all of the important elements intact. A question, however, does not retain all those elements that make up a

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problem (O'Connor, 1996, p. 74-76). It is not the situation made smaller, but only part of the situation (MacMullin & Taylor, 1984, p. 95). They propose a continuum which proceeds from question to problem to sense-making across the solution/problem-solving space. As actors move along this continuum, information needs become less definite and responses to those needs more difficult making information retrieval from systems less valuable while those from "information doctors" or Subject Matter Experts more valuable. MacMullin and Taylor identify a number of information traits that are directly related to dimensions of a problem. Their "solution continuum – single solution/option range" directly relates to the solution/problem-solving space. "The criteria which define a situation yield a distribution of possible good and bad solutions. There may be one desired 'best' solution or, in some cases, any number of solutions will do. Satisficing or finding the first solution that meets minimum criteria is the standard operating procedure of the engineer. Gerstenberger and Allen, in their study of engineers and choice of information channel noted that "Engineers, in selecting among information channels, act in a manner that is not necessarily to maximize gain, but rather to minimize loss. The loss to be minimized is the cost in terms of effort, either physical or psychological, which must be expended in order to gain access to an information channel (Gerstenberger & Allen, 1968, quoted in MacMullin & Taylor, 1984, p. 100).

Within the solution continuum, information is collected until a reasonably good solution is identified especially if cost and other functional factors are met. The range of solution options developed are typically dictated by the importance and degree of structure presented by the problem state. If a problem presents a state of high

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uncertainty, it may require development of a wider range of solution options before the final solution can be agreed. In addition, development of a range of solution options is part of the sense-making process in which the actors are engaged as they work to understand the particular dimensions of the problem.

Problem dimensions are characteristics that establish the criteria for judging information relevance to a specific problem or to a class of problems presenting different contexts. The list below lists them as dichotomies but many exist as continua:

- Design/discovery
- Well-structured/ill-structured
- Complex/simple
- Specific goals/amorphous goals
- Initial state understood/not understood
- Assumptions agreed upon/not agreed upon
- Assumptions explicit/not explicit
- Familiar pattern/new pattern (novelty)
- Magnitude of risk great/not great
- Susceptible/not susceptible to empirical analysis
- Internal/external imposition

The BSIP will be called upon to reconcile information and meaning - to “translate, negotiate, triangulate, and simplify” - for each problem dimension that presents itself in the solution/problem-solving space so that the contributing actors can work together in a meaningful way.

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Boundary Objects and Boundary Spanners

For work to be conducted successfully by diverse groups of actors in complex organizations, cooperation is required to create common understanding, to ensure reliability of information across domains and to gather information that will retain its integrity across time and space. These actors, coming from different social worlds, must try to solve complex problems in this intersecting space. The intersection of these worlds may create tensions between the actors as problem solution and resolution requires creation of new findings dependent on communication and establishment of mutual *modus operandi*. The new findings or artifacts developed as a result of this intersectional work across and between social worlds are termed *boundary objects*.

The term boundary object refers to "an analytic concept of those scientific objects which both inhabit several intersecting worlds…and satisfy the informational requirements of each of them. Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites…These objects may be abstract or concrete. They may have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting social worlds" (Star & Griesemer, 1989, p. 393). Star and Griesemer cited examples of scientific objects that fit the definition of boundary object based on Joseph Grinnell's work during his tenure as Director of the Berkeley Museum of Vertebrate Zoology. These objects included species and subspecies of mammals and birds and their

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habitats, and the terrain and physical factors (temperature, rainfall, and humidity) in the state of California. Star and Giesemer further describe boundary objects stating, "…the objects of scientific inquiry inhabit multiple social worlds, since all science requires intersectional work…the objects originate in and continue to inhabit different worlds…Their boundary nature is reflected by the fact that they are simultaneously concrete and abstract, specific and general, conventionalized and customized. They are often internally heterogeneous" (1989, p. 393 & 408).

Boundary objects, then, provide a means of translation amongst and between the groups or small worlds engaged in navigation of the white space between their respective boundaries. However, new objects mean different things in different worlds requiring the actors to reconcile these meanings if their collaboration is to be successful. This reconciliation of meanings requires the contributing actors to "translate, negotiate, triangulate, and simplify in order to work together" (Star & Griesemer, 1989, p. 389).

The concept of boundary spanning across multiple small worlds has not only been applied to boundary objects but also to people holding roles that span across different small worlds - boundary spanners. Star and Griesemer used the term "marginal people" to identify those individuals who inhabit more than one social world and cite 'marginality' as a critical concept for understanding the ways in which the boundaries of social worlds are constructed and the kinds of navigation and articulation performed by those with multiple memberships (Star & Griesemer, 1989, p. 411). This role brings overlapping place perspectives to bear on the function(s) performed and is responsible for executing "the central cooperative task of social worlds which share the same space

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but different perspectives - the 'translation' of each other's perspectives" (Gerson & Gerson, 1976, quoted in Star & Griesemer, 1989, p. 413).

Research participant 1, assigned the non-identifying descriptor Boundary Spanner-in-Practice (BSIP1), provided context for translation of problems and symbology in the following case story:

> *BSIP1: We were solving a problem in mechanical engineering and I applied electrical engineering because it formed, to me, an easier visual to solve it. So, I was solving a mechanical engineering problem with electrical engineering terms. When you are representing a systematic problem to someone that is not a systems person, you have to find a correlation of something modeling the same situation so they can understand it. You've heard people explain things like this many times, "it's sort of like if you're doing this" and it has nothing to do with the system or what you are talking about but it is a representation that they can grasp. Once they grasp the concept, now they may have input because now they have a base in that area to help solve the problem. So, if I understand it, it's like this; it's a similarity but it's in a different environment. So, sometimes you can solve problems in one environment using knowledge base for another environment. So when I was looking at this layer (pointing to the Copeland/O'Connor model), I was looking at similar disciplines or similar things that are in common and then binding them together with what they have in common, common math, maybe common technical terms, maybe the expertise of solving complex problems. In the other example, where you are calling on*

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different SMEs with completely different types of skills, the skills themselves can be interrelated because they are still part of the, call it, natural science base. We have applied science differently but some of the laws, whether electricity or mechanical or whatever, those laws are still the same. (BSIP1 personal communication transcript of video recording November 17, 2012).

Boundary spanners have been shown to play a mediating role in many organizations and corporations (Di Marco et al., 2010). A new term, the role of boundary spanner is not new; reference librarians and database specialists have filled this role in libraries for many years (O'Connor, 1996). In 1977, Wilson suggested that these new information professionals "might occupy the interstices in the present array of professions" (Wilson, 1977, p. 117). These boundary spanners are useful partners in the search process as they bring the ability to map patron representations of sought-after information or subjects to those in the collection. Their ability to translate patron's needs with that of the collection through their intimate knowledge of the categories and taxonomies employed allows engagement of the formal sign system, the catalog or database interface, using an appropriate set of terms or level of specificity. The boundary spanner can also provide linkages between clusters of documents based on the attribute palette constructed through iterative interactions between the patron and the boundary spanner – in this case, the reference librarian or database specialist.

The literature on Knowledge Management (KM) has emphasized the organizational importance of individuals performing boundary spanning roles (Cross & Parker, 2004; Davenport & Prusak, 1998; Hargadon & Sutton, 1997; Pawlowski &

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Robey, 2004; Steinheider & Al-Hawamdeh, 2004; Swan & Scarbrough, 2001). Cross and Prusak (2002) and later Cross and Parker (2004) studied numerous informal networks in large organizations to identify actors whose performance is critical to organizational productivity. Cross and Prusak identified four critical linking roles:

- Central connectors link most people in an informal network with one another. These individuals are typically seen as the "go-to" person for others seeking information within the network or social world. Most central connectors serve their organization in positive ways, linking colleagues and increasing productivity but some can create bottlenecks acting as barriers to information flow.
- Boundary spanners are characterized as vital individuals who facilitate the sharing of expertise by linking two or more groups of people separated by location, hierarchy, or function (Cross & Parker, 2004). Cross and Prusak (2002) and Wachner and Arthurs (2007) identified boundary spanners as those individuals who connect an informal network with other informal networks, other parts of the company or with similar networks in other organizations. They consult with and advise individuals from numerous other departments regardless of their own affiliation or membership.
- Information brokers keep the different subgroups in an informal network together. If they didn't communicate across the subgroups, the network as a whole would splinter into smaller, less-effective and more isolated segments. Information brokers play a role similar to that of boundary spanners; however, their role only spans within a specific informal network or social world.

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- Peripheral specialists are those individuals that anyone in an informal network can turn to for specialized expertise within their knowledge domain. They serve a vital role in the network by serving as subject matter experts; they possess specific kinds of information or technical knowledge that they pass on to other members of the group as it is required. Peripheral specialists are intentionally on the edge or boundary of a network. These individuals need to stay on the cutting edge in their chosen field so typically do not invest much time cultivating relationships within their network or social world.

In 2002, Williams explored major factors that influenced effective collaborative behavior and boundary spanner competence. His work focused on developing a competency framework for boundary spanners which included the skills, abilities, experience and personal characteristics that contributed to effective interorganizational behavior. “The concept of ‘competency’, which is often used promiscuously (Sandberg, 2000), in this context, is taken to mean, “an underlying characteristic of a person in that it may be a motive, trait, skill, aspect of one’s self-image or social role, or a body of knowledge which he or she uses’ (Boyatzis 1982, p. 21 quoted in Williams, 2002, p. 113).

Williams’ competency framework for boundary spanners identifies four major competencies:

1. Building sustainable relationships – the ability to forge effective working relationships and a readiness to visualize reality from the perspective of others. Collaborative encounters involve the management of difference

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including roles, responsibilities, problems, accountabilities, cultures, professional norms and standards, aspirations and underlying values. Some of the more important skills for this competency include:

- Communicating and listening – the ability to:
    - Use and interpret 'professional language and jargon
    - Express oneself and one's position with clarity
    - Search for shared meanings
    - Utilize 'active listening' techniques
- Understanding, empathizing and resolving conflict – the ability to:
    - Illuminate the perspectives, roles, problems, priorities, motivations, styles, and values of prospective partners
    - Manage conflict and criticism but a willingness to progress without harming the relationship
    - Leverage personality traits, characteristics and personal values to build and sustain relationships including respect, honesty, openness, tolerance, approachability, reliability, sensitivity, etc.
- Trustworthiness – the ability to demonstrate reliability; deliver on promises; deal fairly and honestly to build and sustain relationships

2. Managing through influencing and negotiation – the ability to develop decision-making models that are premised on consensus, equality and win-win solutions. The skills required to be effective include:
    - Influencing – the ability to be persuasive and diplomatic
    - Bargaining – the ability to gain concessions in a negotiation

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- Negotiation – the ability to compromise; to make careful judgements about the balance between benefits and detriments for their and other organizations
- Mediation – the ability to intervene between conflicting parties to promote reconciliation, settlement, or compromise
- Brokering – the ability to successfully broker solutions or deals between a number of different parties; the perceived legitimacy to act objectively and openly for others; the ability to understand the interdependencies between problems, solutions and organizations
- Networking – the ability to develop partnerships undertaken outside formal hierarchical or decision-making structures; the ability to translate interorganizational imperatives and their impact back to the individual participant organizations

3. Managing complexity and interdependencies – the ability to:
    - Make sense of the structure and process of collaboration
    - Deal with disparate bodies of technical knowledge and professional expertise
    - Leverage different connections and interrelationships across the different stages in the partnership and project
    - Manage the interdependencies of interorganizational experience, transdisciplinary knowledge and cognitive capabilities
    - Leverage insider knowledge of different cultures, ways of working, roles and responsibilities and past networks

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- Demonstrate technical knowledge in an area of expertise to demonstrate legitimacy as a boundary spanner

4. Managing roles, accountabilities and motivations – the ability to:
    - Understand the configuration of roles and responsibilities within an existing or emerging interorganizational domain
    - Appreciate the political and professional sensitivities and sensibilities within the interorganizational structure
    - Manage multiple accountabilities as part of the boundary spanner's role as both an organizational and interorganizational representative and partner

BSIP1 offered personal context on the necessity for a BSIP to reconcile meaning through translation, mapping, negotiation, debate, and simplification as well as competency to manage problem complexity and representation in the PSS:

> *BSIP1: I have always taken the tack that the more complex the problem is, then you need to approach the solution in at least three different ways. Normally, the first solution is the more common path that most people would take or appears to be the clearest solution or way to solve the problem. The second solution should not borrow from the first; it needs to be a completely different solution. It should normally be a completely different path with a few similarities but maybe not. By the time that you look to create a third entirely different solution; if you are able to, then you probably should look for a fourth. There may*

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come a point where you say, I can't think of anything different. At this point, your last and final solution will borrow from all your previous solutions and normally you may find…a more perfect solution by combining aspects of all the previous solutions. So, to answer your previous question, somebody bringing a different perspective - if you have already exhausted your other solutions – there may be bits and pieces or maybe the entirety of the solution that they're bringing, you should be able to see either extreme benefits or that it is not going to be worth considering. My experience has shown me how certain solutions have come to bear. I have had many, many experiences where without having gone to the second or third or fourth solution we would have come up with an inferior solution, something that would have worked, but that was not the best solution. Maybe not the simplest, less cost effective or whatever other measures you want to use on it. I think that having multiple approaches, having three different SMEs that have different frameworks to approach a problem, there may be some solutions that come to bear that independently would not have been there because of a different approach.

In the example I gave earlier, solving a mechanical engineering problem using electrical engineering expertise - the electrical model was very apparent to everybody that the solution that had been presented in the mechanical model would never work. But in the mechanical model it appeared to be more complex, even for mechanical engineers, as they had created the solution initially and yet in a different space it became very apparent that this is not solving the problem.

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BSIP4: Was it because of the representation that it looked more complex in the mechanical space as compared to the electrical space? Or was it because there were more variables that they were attempting to bring to bear in the mechanical space than the electrical space? Help me understand why it was more complex in the mechanical space than the solution appeared to be perhaps untenable as compared to representing it in the electrical space?

BSIP1: Let me answer that in two ways. One, my assumption was that the mechanical engineer that had originally proposed it was fully capable and as such, his expertise would have been such that when he's looking at a solution just like I look at a solution in my space and can really see something that looks like it's going to work or not then he would have had that same expertise. If he did, then the representation, the way he was approaching it, must have been more complex and made it not as clear-cut. In my context, the information was presented in an entirely different format and it stood out clearer. The clarity of it stood out.

BSIP4: So it was the representation of the solution being more clear-cut. Would you say that there was less noise?

BSIP1: Yes.

BSIP4: Why?

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BSIP1: The information, in presenting it in a mechanical format, was a context that everybody was familiar with. They basically had a resolution to equations or an approach that had been standardized. On my side, it was a difference of an entirely different look to the same problem so the expectations were not the same. People had to look at the problem differently. Because at first they had to see the representation in a different format so when they saw the solution, it was like "oh, ok, I see it differently." And you've seen it in a lot of things, too. Where somebody talks about it in their space and somebody else looks at it and says, "Well, why don't you just do this" and, boom, the problem is solved differently.

BSIP4: So did all the people that were looking at the solution, from first the mechanical and then the electrical perspective, two contexts for the same problem – were they expecting it to come out as a representation within the mechanical engineering space and was it a surprise that it could be represented in a very different space, the electrical space, and that was what helped them bring this clearer vision because the electrical space obviously gave them a better cleaner understanding of what the problem was and how to solve it? And the other question I have is, if you are representing it in that different a way, were the people that it was being presented to, all SMEs in their own right, could they see and understand what was being represented in both the mechanical space

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and electrical space and that's why when it was presented in the electrical space they said, "oh, much easier, much better, we understand this, we can do this."

BSIP1: The problem was the mechanical solution had been implemented and it had failed to generate the results they were looking for. In looking at the solution that they had proposed - and I represented in a different format - it became crystal clear to them why the mechanical solution had failed. It was not apparent in the original solution. It had been presented to different mechanical engineering functions and even higher level functions and they had all agreed via the approval process. When they saw it in the electrical format, they all said, "Oh, we missed something here."

BSIP1: So who was the catalyst in taking the solution which had been represented in the mechanical space and re-representing the problem in the electrical space and then re-presenting it to the SMEs that had to both understand that there was a solution at hand, a better solution at hand, and then it had to be run up through the various approving authorities to actually implement the solution because it was a much better solution than what the mechanical solution represented. Because if you already have a solution, but it's not a very good solution, but it is a solution, there still has to be a catalyst to take the problem and re-represent it and says that there is a better way to do it.

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BSIP1: The situation was that they had come to me to answer why it had failed. I took the studies that they had done in mechanical and it was apparent to me, looking at some of the mechanical parts of it that they had not really solved the problem. Not because it actually had occurred that way but in the approach to the problem but there seemed to be a missing piece here so I searched putting the problem together in a different context – again, you are solving a problem with different scenarios. I took it in my context and said let's solve it in a different way.

BSIP4: So was it different input or different variables you had to use to re-represent the problem in a better way? You had ingested all the information that they had presented in this problem space. What did you specifically bring to bear that they had been unable to bring to bear from an expertise perspective?

BSIP1: The different modeling. In the modeling - all the parameters had to be converted. In other words, what you see as flow parameters in mechanical engineering had to be represented as current or resistance or in one case parallel circuitry and the translation is easy from the standpoint if you understand the mechanics or you understand the science you are able to take some of that and translate it and say, this is essentially the same thing. The current was the flow; the pressure was the resistance.

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BSIP4: So a lot of that becomes not just taxonomy, it actually requires translation of the variables from one format - as far as representation - to another. So again, we've got this, the dynamics of communication or in this instance it is the dynamics of translation of symbology so that the communication can go from the [communication] dynamics in the mechanical engineering space to the [communication] dynamics in the electrical engineering space. Is that correct?

BSIP1: Correct. Now, I know for sure that it could have been represented in the mechanical space, probably in a different format that would have brought the same conclusion.

BSIP4: So, when you're talking format, though, would that just be the symbology that's required for mechanical engineering vs. electrical engineering?

BSIP1: Correct. It may even be if you were looking it from a systems perspective, when you're looking at nodes, and you're saying that I have these different nodes of communication, it could have been represented in a different format that somebody in a communications major might say "oh, that's clear cut." So electrical was simply a different way to represent it. And the mechanical was not as obvious. Once I had represented it in electrical, the mechanical people looked at it and said, "Yeah, we see it." And they could [then] see it in a mechanical format.

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BSIP4: So they also had enough understanding of the symbology and realized that when the variables were translated from mechanical space to the electrical space, they also saw that there was a better solution that was provided so then they also bought in on this, yes?

BSIP1: Correct. The translation was presented to them; in other words, their understanding of fluid flow and the translation into electrical, that had to be communicated to where they understood that but once they understood that, it looked like a clear cut model for them. They were able to grasp it. So again, there was a translation involved and they were able to see it but again it was put into a perspective getting back to where they understood it.

BSIP4: Putting it into a context…

BSIP1: your third dimension…

BSIP4: [of] this problem [solving space]… so that they would have an understanding and a context that they could embrace the solution within the confines of their expertise.

BSIP1: Correct, because it was not literally an electrical problem or electrical representation, it was electrical symbolism I used. In other words, I

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didn't go in there and say, "Ok, the resistance is 10k Ohms and the current is so many Amps." It's just, you have current 1, current 2, resistance 1, resistance 2 and you were building the resistance of…so, it was your third dimension. It was just like when you and I talked about math - when you're baking a cake; cake is equal to the sum of all these different ingredients….so much flour, sugar, butter, so many process steps, whatever you have to do…bake it to make it and that's white cake. If I'm going to make chocolate, I can add chocolate to both sides of the equation and now I might have to do it in the right order but I've added chocolate to both sides and now I've got chocolate cake. It's a mathematical representation yet to somebody it's more of a symbolic representation of how I make a cake, it's not a mathematical model. It's just symbolic of how I do things. So some of it is performance-based and some of it is just how you model it. So that's why I say, that sometimes when you have interaction you're looking at the symbolism of the information so that at a point or a level, that all people can be on the same page. That's what I call the "binder" - that basically means, what do we have in common? We're given brain power, is it mathematical knowledge? Is it systems knowledge? Is it science knowledge? Communication - same language? (BSIP1 personal communication transcript of video recording November 17, 2012).

BSIP2 brought another aspect of Disposition and Personality into focus as the discussion of BSIP competency progressed:

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BSIP2: ...the Johari window, for example, says that every single one of us has four panes that we operate off of. One of the window panes is the unknown; that's the element that you don't know and other people don't know about you...that's when you have surprises. And those surprises can pop out in the action and interaction that goes on in the team and can waylay it. It can throw it off-center, it can keep it from bringing in the goal or objective; it keeps them from succeeding which is the very reason that they've come together. (BSIP2 personal communication transcript of video recording January 20, 2013).

The Johari Window

The basic Johari Window is a simple and useful way of demonstrating how "the self" is divided into four parts that we and others may or may not see. These four parts or aspects of 'self' lead to four different personas, based on which self is the largest component for each individual.

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Table 2

The Basic Johari Window

	What you see in me	What you do not see in me
What I see in me	The Public Self	The Private (or hidden) Self
What I do not see in me	The Blind Self	The Undiscovered Self

Note. Adapted from "*The Johari Window: a graphic model for interpersonal relations,*" by J. Luft, and H. Ingham, 1955, Berkeley, CA: University of California Western Training Lab. Copyright 1955 by the University of California Western Training Lab.

The four parts of self include:

1. The Public Self is the part of ourselves that we are happy to share with others and discuss openly. Thus you and I both see and can talk openly about this 'me' and gain a common view of who I am in this element.
2. The Private Self is the part of ourselves that are too private to share with others. We hide these away and refuse to discuss them with other people or even expose them in any way. Private elements may be embarrassing or shameful in some way. They may also be fearful or seek to avoid being discussed for reasons of vulnerability.

Between the public and private selves, there are partly private, partly public aspects of ourselves that we are prepared to share only with trusted others.

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3. The Blind Self is that part of ourselves that others have of us which may be different from those we have of ourselves. For example a person who considers them self as intelligent may be viewed as an arrogant and socially ignorant by others. Our blind selves may remain blind because others will not discuss this part of us for a range of reasons. Perhaps they realize that we would be unable to accept what they see. Perhaps they have tried to discuss this and we have been so blind that we assume their views are invalid. They may also withhold this information as it gives them power over us.
4. The Undiscovered Self is the self which neither we or nor other people see. This undiscovered self may include both good and bad things that may remain forever undiscovered or may one day be discovered, entering the private, blind or maybe even public selves.

Between the Blind and Undiscovered selves are partly hidden selves that only some people see.

The four personas described below are based on which "self" is the largest for each individual:

1. The Open Persona
    - Someone with an open persona is both very self-aware (with a small blind self) and is quite happy to expose their self to others (a small private self).

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- The Open Persona is usually the most 'together' and relaxed of the personas. They are so comfortable with their self they are not ashamed or troubled with the notion of other people seeing them as they really are.
- With a small Blind Self, they make less social errors and cause less embarrassment. They are also in a more powerful position in negotiations, where they have fewer weaknesses to be exploited.
- Becoming an Open Persona usually takes people much time and effort and requires courage to accept others' honest views and also to share the deeper self.
- The weaker side of the Open Persona: while they understand and share their self, they may also share embarrassing information from their Private Selves with others who are not ready to accept it.

2. The Naive Persona

- The Naive person has a large Blind Self that others can see. They thus may make significant social gaffes and not even realize what they have done or how others see them. They hide little about themselves and are typically considered as harmless by others, who either treat them in kind, and perhaps patronizing ways (that go unnoticed) or take unkind advantage of their naivety.
- The weaker side of The Naive Persona: they may also be something of a bull in a china shop; for example, using aggression without realizing the damage that it does, and thus can be disliked or feared. They may

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also wear their heart on their sleeves and lack the emotional intelligence to see how others see them.

3. The Secret Persona
    - When a person has a large Private Self, they may appear distant and secretive to others. They talk little about themselves and may spend a significant amount of time ensconced in their own private world. In conversations they say little and, as a result, may not pay a great deal of attention to others.
    - The weaker side of the Secret Persona: Having a smaller Blind Self (often because they give little away), the Secret Persona may well be aware of their introverted tendencies, but are seldom troubled about this. Where they are troubled, their introversion is often as a result of personal traumas that have led them to retreat from the world.
4. The Mysterious Persona
    - Sometimes people are a mystery to themselves as well as to other people. They act in strange ways and do not notice it. They may be very solitary, yet not introverted.
    - The weaker side of the Mysterious Persona: As the Mysterious Persona knows relatively little about their self, they may be of low intelligence, not being able to relate either to themselves or to others. Alternatively, they may simply prefer to live in the moment, taking each day as it comes and not seeking self-awareness.

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- Some forms of esoteric self-development seek to rid oneself of concerns about the self in order to achieve a higher state of being. They may deliberately enter states of non-thinking and revel in such intuitive paradoxes as knowing through not knowing.

Competent BSIPs will push the boundaries to become more open and public (if this serves their interests) by seeking honest feedback from others. They will most likely seek to discover more of their Blind Self leveraging this information to improve their competencies in negotiating with and persuading others.

Within engineering networks, research has focused on the mediating role of boundary spanners in three areas (Di Marco et al., 2010). The first area focuses on how cultural boundary spanners can resolve cross-cultural knowledge system conflicts thereby increasing collaboration effectiveness. This can include a range of subjects from differences in linguistic norms (sign systems) to execution of work packages by multiple non-collocated teams. Until the multiple contexts can be resolved to a single social norm for the multiple small worlds engaged globally in execution of work packages for a project, the realization of performance improvements as a high performance team is at risk. The second area focuses on how boundary spanners can resolve differences in local work practices which can impede information flow due to misunderstanding of critical information embedded in boundary objects. While some might view this as simple “expediting”, many of the underlying gaps in performance appear to stem from differences in base knowledge, understanding of standards and procedures executed regionally, etc. (Examples could include surveying techniques,

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norms involving work execution calculations - by month rather than by day, etc.) Lastly, work undertaken by Levina and Vaast (2005) focused on how nominated boundary spanners can help multinational teams pursue common goals through the creation of "joint fields." This harkens somewhat to Lewin's topological approach to social networks (Lewin, 1936) where regions (small worlds) were defined by paths running with but not between regions. Here, boundary spanners are nominated specifically to bring multiple global / regional small worlds together helping to bridge the white space between them.

This mediating role played by boundary spanners serves to create common understanding across the social norms of each small world in which they engage with considerable time spent translating between viewpoints. Boundary objects, standards and operating protocols, linguistic and social norms mean different things to actors in different small worlds. Reconciling these meanings can be achieved through translation, mapping, negotiation, debate, and simplification to permit the small worlds to begin to work synergistically (Star & Griesemer, 1989). But before small worlds can begin to work together, even before they begin the process of developing a shared context, they must spend time mapping - words, concepts, meanings, boundary objects and their significance, other "information doctors'" knowledge domains and expertise – to maximize communication across their intersecting small worlds.

Meaning reconciliation and simplification can also require a BSIP to become competent in filtering the significance of information especially in a noisy environment. BSIP1 elaborated on noise and its impact on communication:

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BSIP1: In a noisy environment, they may not hear the entire concept. That may result in partiality as they only picked up pieces. This might not allow the team to hear in an impartial way which will impact the whole space. They may have to act on incomplete information. There are many things in the environment that impact communication. If I have historical information – commonality because you have worked together previously – you may work together differently as compared to people that have never worked together. Perceptions in the space: An engineer may look at things differently than a chemist to start off with but once you start peeling back the onion, you start putting into a common term even though it's not the same space for both of them, the understanding can improve and they can actually solve problems in a third dimension as opposed to the dimension that each one of them is in.

BSIP4: You [as the BSIP] bring a dimension, the SMEs bring a dimension. But the actual problem-solving space – that's where you actually go into a third dimension because they each bring their own dimension based on their individual knowledge bases – a space in which each brings their dimension to the problem-solving space which becomes the third dimension, [the new joint field in the] problem-solving space.

BSIP1: Because you are in this third dimension, there are points that are intersecting, that are in common, maybe not specifically the same information but

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similar. The points can be intersecting, perhaps not quite in common, but similar. You are able to build a new field...in which their understanding is similar.

BSIP4: Noisy environments; too many times when you are in the problem-solving space, you don't really take time to identify what people consider to be valuable vs. noise? That's what I tried to represent in the proposal in the k gaps charts. How much of the noise is due to directed problem solving versus noise produced from communication dynamics and mechanics as part of the development of shared understanding. Some of the noise in the PSS comes from the development of common understanding especially in the context of historical information – team members that have worked together previously. Team members with a history – who have already developed shared understanding or context - reduce the noise that comes from the team building process (storming, norming, etc.).

You can set some of the queries aside in the third dimension of the PSS that are part of the development of trust and shared context. When you bring new SMEs into the problem-solving space, is there a way to get past the positioning – who brings what to bear in this space, identifying their experience – and engaging in a directed manner to solve a problem if you don't know the depth and breadth of their experience.

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BSIP1: You are talking about interference noise – I'm talking about noise that may be preventing someone to seek or understand. It may be not interaction noise but noise from impact of experiences.

Let me give you an example that might help:

I was brought in to a situation with a group of experts that were trying to problem solve. They had very directed presentations on the problem and they did an information share for over an hour. Once they were through, they asked me now that you have seen the problem, do you have any way to solve it? And it was all noise. It was noise because my need for information was at a different level than what they were presenting at. Their presentation was based on their own space, on their own concept of what the problem was. We all understood what the problem was but we were at different levels for the approach. What they were presenting as an opportunity was in their space, not in a problem space or level in which I could interact with completely. I understood their space, I understood their problem – but there was noise from a conceptual basis. Once I approached it within a different framework, I was able to bring information that ultimately resolved the problem. It's not necessarily confrontational noise, it may be body language or semantics; someone is reading something that's not there or visualizing/approaching something that really isn't accurate or necessarily there – that's a different type of noise. Many times when you are trying to communicate with people – have a serious conversation - in a very noisy place, we may take different outlooks from it. Yet if we were in a sports arena versus a dance hall versus a church environment there are different environmental factors

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that come into play. Interactions using the same words would be taken differently.

BSIP4: So the context brings different interpretations to bear…

BSIP1: Right! So when you have different SMEs/people that are trying to work together in an environment, if one is experiencing physical pain or something else, their reception will be less - which is another environmental factor. So when I was talking about the "bind" that brings everybody together – the "bind" is the thing that basically works for everybody. In other words, I need to be pain-free in order to interact with you so you need to get me to that state. That's the binding that we have. If I'm a different discipline, the "bind" may be that I need to understand how to present a problem in a context that you can understand it or another discipline can understand it. That's the third dimension – everyone understands it. If it's the words, the semantics, the words may be the bind – I need to find semantics that we both agree upon so that we have positive interactions.

Organizational competence in boundary spanning emerges "in practice" by drawing on the concepts of boundary spanner and boundary object. Sociologists use the concept of "practice" to understand the dynamics of societies based on what people do (Bordieu, 1977; Certeau, 1984; Giddens 1984). The term "practice" refers to "a recurrent, materially bounded and situated action engaged in by members of a

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community" (Orlikowski 2002, p. 256 quoted in Levina and Vaast, 2005, p. 337). Through practice, actors engage in producing, reproducing, or transforming artifacts which, in turn, enable and constrain their actions (Bordieu, 1977; Certeau, 1984; Giddens, 1984). The ability of an organization to build practices that draw on diverse bases of expertise constitutes one of the key organizational competencies in knowledge management (KM). The proposition that spanning boundaries of diverse professional and organizational settings can become a key organizational competence has been reported in the literature (Grant, 1996; Kogut and Zander, 1992; Nonaka, 1994; von Hippel, 1988).

The literature on boundary spanners highlights the importance of assigning the role of boundary spanner as a way of developing organizational capability to manage the challenges of managing across boundaries. However, some actors who have not been officially nominated through appropriate organizational channels and hierarchies to perform this role may still act as boundary spanners (Nochur & Allen, 1992). Nochur and Allen suggest that the expectations of the role and the practice of boundary spanning often do not coincide. This introduces a distinction between 'nominated boundary spanners' and 'boundary spanners-in-practice' (BSIP). In contrast to nominated boundary spanners, boundary spanners-in-practice must actually engage in boundary spanning, relating practices in one field to practices in another by negotiating the meaning and terms of the relationship. The engagement in translation and negotiation thereby results in the building of a new joint field between the two fields of practice – a third dimension is co-jointly developed between the two fields or *dimensions* that the boundary spanner works to bridge.

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Levina and Vaast (2005) identified three required conditions for an actor to become a BSIP:

1. Becoming a BSIP requires becoming a legitimate, but possibly peripheral, participant in the practices of both fields as it requires the ability to negotiate relationships between the involved practices and requires the development of at least a minimal understanding of each practice. BSIPs must be legitimate participants in each field who can gain access to the practices and artifacts of each (legitimacy) having a stake in both fields and in the reproduction of each fields' practices (participation).
2. BSIPs must have legitimacy, not only as participants, but also as negotiators on behalf of the fields whose interests they are to represent. BSIPs are seen as the actor capable of reshaping the practices in the fields for which the actor serves as a representative.
3. Actors engage in boundary spanning because they develop an inclination, not necessarily a conscious motivation, to do so which may derive from perceived advantages associated with boundary spanning.

BSIP1 validated the importance of communication and attitude of the contributing actors engaging in boundary spanning activities in the problem-solving space:

BSIP1: I called this the binder between all the different layers. What binds everything together is the assumption that the SMEs and BSIP are all geared towards solving the problem. This must be the common assumption. Then you

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have other things that can be considered binders – you've worked together before in the past or you have certain other fundamental commonalities [shared context]. In some cases, it's not the lack of fundamental commonalities, it's the communication process itself. Communicating – if two people are interested in communicating, they will find things that are in common. If one person is trying to be dominant, the other person has [a reaction] - either they will accept the dominance or there will be a conflict. You can also observe body language to help understand the acceptance of the situation. Then you get into semantics – one person's understanding of something being "acceptable," the word "acceptable" may have different meanings as well. You need similar communication styles and communication interpretations. (BSIP1 personal communication transcript of video recording November 17, 2012).

Levina and Vaast distinguish between designated boundary objects and boundary objects-in-use. Actors who hold positions of power in relevant fields designate certain objects as valuable for boundary spanning. But these designated boundary objects may not become boundary objects-in-use. Based on the original definition by Star and Griesemer (1989), to become a boundary object-in-use, the artifact must prove locally useful (i.e., be meaningfully and usefully incorporated into practices of diverse fields) and must have a common identity or structure across fields. Here, 'common structure' refers to a structure that "is common enough to more than one world to make them recognizable" (Star and Griesemer, 1989, p. 393). A common identity or structure can only be acquired through development of a joint practice. Therefore, the emergence

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of boundary objects-in-use is intrinsically tied to the emergence of a new joint field or dimension.

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RESEARCH

The goal of this research is to further inform and refine the Copeland and O'Connor Nondeterministic Model of Engineering Design Activity, adapted from Copeland (O'Connor, Copeland, & Kearns, 2003, p. 141), bringing the foundations of information philosophy (Wilson, 1977, 1983; Chatman, 1991, 1998) to the conduct of complex knowledge work.

This model resulted from examination by Copeland and O'Connor of engineering design activity and, as a construct, the representation is functional, pragmatic, contingent and satisficing presenting a graphical way to grasp and manipulate concepts. However, it is important to note is that the model was developed to explain design activity at the level of a single nondeterministic user – an engineer, a bounty hunter, and a submarine chaser.

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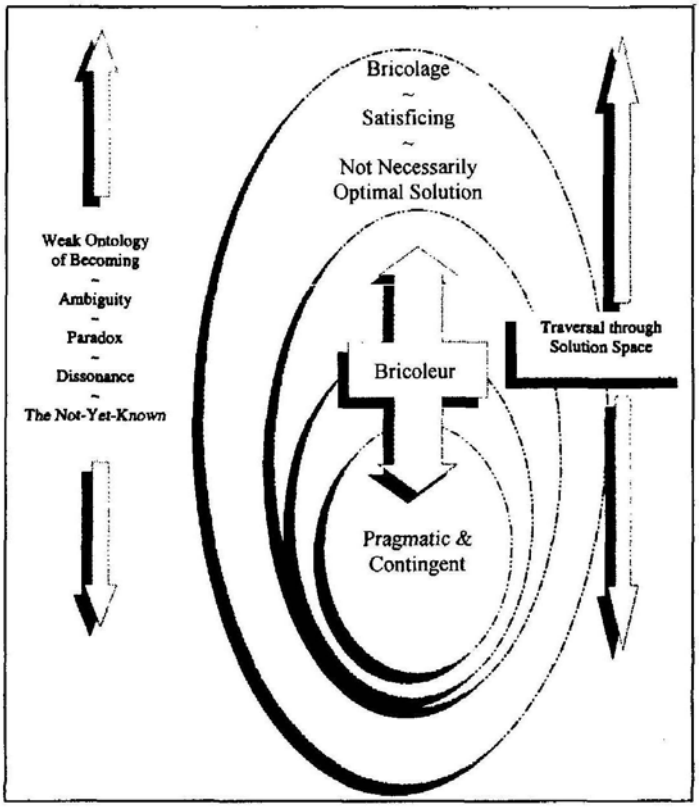

Figure 2. Nondeterministic model of engineering design activity. Adapted from "Hunting and gathering on the information savanna: Conversations on modeling human search abilities," by B. C. O'Connor, J. H. Copeland, and J. L. Kearns, 2003, p. 141, Lanham, MD, & Oxford, UK: The Scarecrow Press, Inc. Copyright 2003 by The Scarecrow Press, Inc.

Research Questions

- How can the model be further informed to address the mechanics and dynamics in which boundary spanners-in-practice (BSIP) engage with one or multiple small world Subject Matter Experts?
    - How does the model change in aggregate when multiple simultaneous interactions of the single nondeterministic user model engage during design activity?

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- How can the model represent expertise seeking behaviors and the physical and mental models constructed by boundary spanners during knowledge domain mapping?

Boundary spanner mechanics focus on the exchange of information and explicit knowledge domain mapping afforded by bridging multiple small world knowledge environments. This exchange can result in a production of a new joint field, a new knowledge domain or an entirely new knowledge base.

Boundary spanner dynamics focus on the exchange and sharing of information and tacit knowledge domain mapping. Boundary spanners-in-practice spend significant time in tacit knowledge environments translating, mapping, and navigating small world knowledge domains and assets. BSIPs are drawn together with one or multiple Subject Matter Experts and associated small world(s) to solve a problem or problem set which can create new knowledge entities and perhaps new problem-solving tools.

If a more informed model depicting the mechanics and dynamics of boundary spanners can be developed, the model could be more broadly applicable to those industries which employ large numbers of knowledge workers including engineering, the library and academia, knowledge management practitioners, etc. By identifying the enablers required to successfully develop cross-industry practices and domain expertise, BSIPs can become the crucial bridges to support corporate changes in strategy and direction while helping them to remain competitive in the marketplace. Lastly, in the engineering space there could be numerous opportunities to leverage a model that integrates expertise development, BSIPs and boundary spanning through

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already established frameworks or programs including business/operational excellence, functional excellence frameworks, continuous improvement, organization development, learning and development, information management, social networks and media, business process improvement, etc.

Research Method

The Grounded Theory research methodology (Glaser & Strauss, 1967) will be employed to explore the research questions posed. As a research methodology, Grounded Theory is a discovery-oriented approach to research offering a way of conceptualizing similarities of experience of an aggregate of individuals (Rudestam & Newton, 2007, p. 43) with theory emerging as the data is analyzed. In a grounded theory study, the investigator seeks to develop a theory that explains process, action or interaction on a topic by collecting data in the form of interviews, observations, events, happenings, documents, etc. Creswell's image for data collection in a grounded theory study is a "zigzag process: out to the field to gather information, into the office to analyze the data, back to the field to gather more information, into the office and so forth" (Creswell, 2007, p. 64). Participants interviewed are theoretically chosen to help the investigator form the theory (termed theoretical sampling) while the "zigzag process" of taking information from data collection and comparing and analyzing it is called the constant comparative method of data analysis.

Much of the research methodology comes from that presented in *Hunting and gathering on the information savannah: Conversations on modeling human search abilities* which utilizes snapshots of ongoing conversations amongst the authors to

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"explore, ramble, and stumble upon ideas with the least prior constraint" (O'Connor, Copeland, & Kearns, 2003, p. 1). Conversation remains the most obvious and fruitful means to tap into the tacit knowledge each BSIP has aggregated across the span of their career. The conversation with each BSIP follows the same path, a continuum which proceeds from question to problem to sense-making across the solution/problem-solving space (O'Connor, 1996, p. 74-76; MacMullin & Taylor, 1984, p. 95) to design a more functional and useful model to support the navigation of the information environment.

Videotaped interviews with Boundary Spanners-in-Practice (BSIPs) will be performed with the researcher as Interviewer. In this way, the researcher will be able to give a careful account of the data collected from a purposive sample of no more than four subject matter experts with relevant boundary spanner-in-practice experience who can give credence to the mechanics and dynamics particular to the BSIP role and to knowledge domain mapping and translation. This sample size and selection of participants may need to be adjusted based on concept saturation and participant availability ensuring the research questions and related concepts to knowledge needs, knowledge domains and mapping are comprehensively explored such that analysis of the data becomes theoretically meaningful (Rudestam & Newton, 2007, p. 107).

BSIPs from multiple industries and multiple countries of origin will be identified as potential participants; research participants will have agreed to the time commitment and identify their experiential base with that of BSIPs.

In-depth one-on-one interviews will be videotaped with participants in a neutral environment to reduce researcher subjectivity. Transcribed notes and conclusions will

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be provided to individual participants for clarification, verification, and review of conclusions.

The interviews will seek to determine comparability of mechanics and dynamics behaviors and physical and mental models constructed by boundary spanners during knowledge domain mapping. By front-loading the data, the model can then be applied to it to assess applicability to broader knowledge engineering activities beyond those engineering design activities that Copeland (1997) investigated. Wilson likened such technical design work not to a science but rather to materials science, an engineering discipline. Materials science studies the properties of materials; Wilson stated that "[s]tudy[ing] the properties of the materials we are interested in leads directly into social epistemology, the social study of knowledge production and use" (Wilson, 2002, para. 3).

Analysis of the transcribed data including the researcher's observations and experiences will need to proceed from initial immersion in the raw data followed by descriptions of the data including summaries and conclusions generated first by the researcher and those provided by participants during the clarification and validation phase and then finally to understanding and interpretation of the data. This process will allow the researcher to make sense of the data within the conceptual framework of the work boundary spanners perform.

The research performed required:

- Identification of BSIP attributes to assess appropriateness of each BSIP candidate nominated for the research project

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- Communicating the intent of the research - level-setting each BSIP participant to ensure the ability to participate fully during the interview(s)
- Securing agreement from each BSIP to participate in the research process
- Level-setting each BSIP participant prior to starting the videotape to ensure each participant had the ability to participate fully during the interview
- Assessing the Nondeterministic Model of Engineering Design Activity in its current form
- Leveraging the BSIPs' knowledge and expertise in boundary spanning practices to inform the model
- Recommending model revisions based on development of a new joint field of practice through collaborative and iterative dialogue with the participant BSIPs
- Assessing the ability to integrate the revised model into a Knowledge Management Framework
- Proposing future research integrating the revised model with other frameworks based on usability testing and client validation performed to-date

Boundary Spanner-in-Practice Attributes

Research participants were identified by characterizing their professional careers and practices against the five types of boundaries identified by Espinosa et al. (2003). A summary table for the BSIP research participants is provided in Table 3.

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Table 3

Breadth of Boundary Spanning Practice by Research Participant

	Types of Boundaries Spanned					
Research Participant	Geographical	Functional	Temporal	Identity	Organizational	BSIP Inclination
BSIP1	• Has led as BSIP or participated as SME on numerous non-collocated/global teams • Has worked in multiple countries across the globe • Multi-lingual (English, Spanish)	• Electrical Engineer • Drillings & Completions Engineer • Telecommunications Business & Marketing Manager	• Has led as BSIP or participated as SME on numerous non-collocated/global teams	• As a BSIP and SME, has been seconded to multiple interorganizational global projects simultaneously • Born in El Paso, TX and raised in a traditional Mexican home, identity – Mexican? American? – is a recognized conflict	• As a BSIP and SME, has collaborated with multiple teams from outside corporations simultaneously	Observed by Interviewer. Validated by Research Participant.
BSIP2	• Completed certification as a Coach (ICF) as an international student • Has built a global coaching practice	• Psychotherapist • Academic Lecturer • Executive Coach (ICF)	• Distance and time zones regularly impact client interactions	• Dual professional roles executed simultaneously; at times, roles can switch hourly.	• Dual professional roles executed simultaneously; at times, roles can switch hourly.	Observed by Interviewer. Validated by Research Participant.
BSIP3	• As a member of an Oil & Gas family, has lived in numerous countries across the globe	• Pacific-coast salmon fisherman • Homeland Security Systems Administrator	• Has led as BSIP or participated as SME on numerous non-collocated/global teams	• As a BSIP and SME, has collaborated with multiple international SMEs on numerous projects simultaneously	• As a BSIP and SME, has collaborated with multiple teams from outside corporations simultaneously	Observed by Interviewer. Validated by Research Participant.
BSIP4	• Has led as BSIP or participated as SME on numerous non-collocated/global teams • Has worked in multiple countries across the globe	• Research Chemist • Risk Manager • Academician • Project Manager, Oil & Gas	• Has led as BSIP or participated as SME on numerous non-collocated/global teams	• As a BSIP and SME, has been seconded to multiple interorganizational global projects simultaneously	• As a BSIP and SME, has collaborated with multiple teams from outside corporations simultaneously	Observed by Interviewer. Validated by Research Participant.

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Research Project Communication - Information Provided to the Candidates

Candidates were provided with a copy of the dissertation proposal via email. Each candidate was also provided with access to a folder on the researcher's Google Drive that contained a copy of the dissertation proposal and a selection of papers providing background on boundary spanners-in-practice and boundary objects. A question and answer meeting was scheduled with each candidate for approximately two weeks from the date stamp of the email to ensure all candidates understood the time commitment, would be willing and able to participate and knew of no professional or organizational barriers that would disallow them to share their experiences.

Candidate Agreement to Serve as Research Participant

Of the original list of seven candidates, five originally agreed to participate in the research process. Of the five, one BSIP elected to withdraw after a voluntary change in employers requiring the participant to sign a non-disclosure agreement.

Research Participants (BSIP) Level-Setting Prior to Videotaping

All research participants (BSIPs) were read all statements in Appendix 1 of this document. Confirmation of approval to both videotape the interview and to participate as a research participant was again confirmed via videotape and prior to the start of the interview.

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Informing and Refining the Copeland and O'Connor Nondeterministic Model of Engineering Design

The Copeland and O'Connor model employs a standard target-style model, one that has been employed numerous times in the literature and across the sciences. In 1999, Dr. Thomas Wilson utilized the target model to point out that information search behavior is a subset in information seeking behavior and that information seeking behavior is in turn only a subset of all possible information behavior. Wilson's target model is also a nested model as each smaller circle in the target represents a subset of the larger behavior of which it is only a part. This nested model could be extended further by showing that information behavior is a part or subset of all human communication behavior. There are numerous models in the field of communication theory (McQuail, 1994) most of which take the Shannon and Weaver (1949) communication model as their starting point.

Models of information behavior do not all attempt to describe the same set of phenomena or activities; some, as in the case of Ellis (1989) are concerned with behavioral patterns in the actual search activity; others, like Kuhlthau (1994) present stages of activity, within which the behavioral patterns may occur. Both the Wilson and Copeland and O'Connor models presented here are of this second type in that problem solving is presented as the overall framework for information seeking activity.

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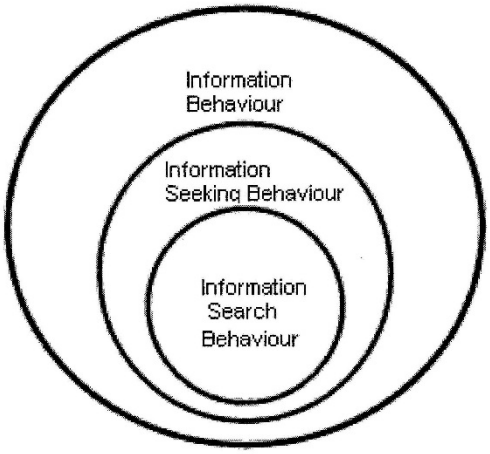

Figure 3. Wilson's nested model of information behaviour. Adapted from "Models in information behaviour research" by T.D. Wilson, 1999, *Journal of Documentation, 55*(3), p. 263. Copyright 1999 by Emerald Group Publishing Limited.

The Copeland and O'Connor model differs from the Wilson model in that as "a schema for an integrated model of engineering design [it] was systematically elaborated from the "inside out," beginning with the "core values" of design activity and then…working out from there" (Copeland, 1997, p. 200). The ellipses reflected the active nature of problem solving activity with the engineer or bricoleur engaging in design activities contingent upon the resources at hand. The product of the bricoleur's activity is a bricolage, "a pragmatic, practical solution to a problem, often a satisficing, less than optimal solution that works in a given design context" (Copeland, 1997, p. 204).

The ellipses in the Copeland and O'Connor model were utilized to "express…an "undivided wholeness in flowing movement" (Bohm, 1980, p. xv) which "create[d] a new structure that is not so prone to fragmentation" (Bohm, 1980, p. 31) as traditional models based on concentric formats" (Copeland, 1997, p. 200). As well, "the circles…reflect the active…nature of human problem solving" (Copeland, 1997, p. 202)

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“act[ing] as a “permeable membrane” that stimulates the “inner flow” among the themes of engineering design while allowing ”outer flow” (Mintzberg, 1994, p. 11-22) with the external environment” (Copeland, 1997, p. 200).

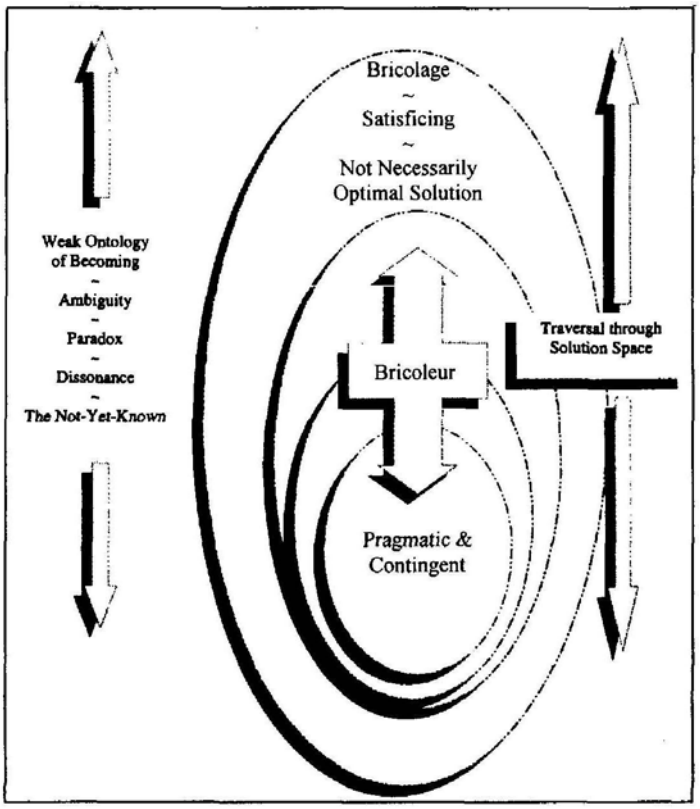

Figure 4. Nondeterministic model of engineering design activity. Adapted from “*Hunting and gathering on the information savanna: Conversations on modeling human search abilities,*” by B. C. O’Connor, J. H. Copeland, and J. L. Kearns, 2003, p. 141, Lanham, MD, & Oxford, UK: The Scarecrow Press, Inc. Copyright 2003 by The Scarecrow Press, Inc.

The assessment of the Copeland and O’Connor model began by gaining impressions of the model by the BSIP research participants:

From BSIP2 -

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BSIP2: When I looked at this initially, I thought of two things. One was that this was like a kernel; you know, a kernel has a very hard shell on the outside of it. The energy or the rich part of the kernel is deep within its core. And so you have to apply a certain amount of heat…

BSIP4: or pressure…

BSIP2: …or some kind of external force to hit that kernel to burst it open to bring forth the richness of whatever is there to be offered. That's what hit me when I looked at it the first time. When I looked at it a second time, I thought about surface tension. You know you have a drop and it comes down and hits the water and we remember from our first physics course the crown pops up around it. Again, it seems as if there's going to have to be some kind of stimulus or some kind of energy that's going to have to come from without that will literally impact or effect upon this to be able to share what's within the nucleus.

I like this model better <points to the reconstructed individual model> because of the fact that it looks like more of an open system. To me, this is a very closed system <points to the Copeland and O'Connor model>. If you look at the way the lines are drawn, it appears that it spirals down and inward instead of being out and upward where it would share with other systems. So to me this is a very confining kind of a model, and restrictive. That <points to the reconstructed individual model> with it being open and again identifying it with other things I have seen, having lived all over, when I first looked at that, it reminded me of

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tractors that I saw in Colorado that would go across the field. They had an apparatus that would break the surface and stir up of the nutrients, the energy of the soil and bring it up, worms and what have you, and other organisms would come and feed on that preparing that for planting, preparing that for growing something up. So I liked that.

Another thing I liked about it was the equal sizes of the circles, because that gives you some sense of respect, that everyone is going to have equal worth, equal trust, equal respect and, hopefully, equal impact, equal input. Like you say, nothing is every perfect and you don't even shoot for perfection – that's not reproducible anyways. But the idea is there that you have these entities that are going to come in and everybody is going to have a piece of it. Another part of that was I like circles because circles are unending, which hopefully means that they can continue regeneration, they can continue the productivity…

BSIP4: …so the knowledge base would be continuing to aggregate additional knowledge…?

BSIP2: …yes, would continue to grow…. There's a sense of those being connected but they're almost like within one another's field, and again, I'm going back to an energy field, because within your model there the distance is equal and so it's almost as if there's a synergy that holds each within its own axis or area of spin. (BSIP2 personal communication transcript of video recording January 20, 2013).

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From BSIP4 -

BSIP4: …to me it looks like layers of an onion. What that kind of model speaks to me about is that the outer layer of that onion is very superficial; everybody has access to it but the deeper you go into the onion it may be more shielded, more guarded. You have less and less access to those layers. (BSIP4 personal communication transcript of video recording January 20, 2013).

From BSIP3 -

BSIP3: Being Non-Deterministic, it's not designed or set to a specific target group… it needs to be fluid and flexible… What I see is kind of an eccentric target, where you have the ideal, the Pragmatic and Contingent in the center and the outer rings are different levels of variables. Again, being eccentric, you can get really off-balance… (BSIP3 personal communication transcript of video recording January 20, 2013).

BSIP1 noted immediately that the Copeland model as represented in his dissertation appeared to only represent only one Subject Matter Expert (SME) in the problem-solving space.

BSIP1: When I looked at the model the first time, I was envisioning multiple similar types of SMEs – multiple engineers from different disciplines but with certain amounts of commonality – math background, problem-solving

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background, the approach of breaking things down into components… things that are similar within disciplines…different layers that different SMEs could bring to bear in the problem-solving space. (BSIP1 personal communication transcript of video recording November 17, 2012).

To begin the informing process for the Copeland and O'Connor model, the first two model iterations were drawn. The model iteration 1 attempted to re-represent an individual SME, their Knowledge and Experiential bases in the problem-solving space. The model iteration 2 attempted to demonstrate how the model changes when multiple simultaneous interactions of the single nondeterministic user model engage in the problem-solving space. This model incorporated a BSIP and two SMEs building on model iteration 1 as part of the design activity. In model iteration 2, the drawing of the Boundary Spanner and the two SMEs were represented on the same plane, a communication plane which came out of the discussion with BSIP1:

BSIP1: (Refers to one of the diagrams drawn during the session with a BSIP and the SMEs) Even in drawing this model, the SMEs have to be on the same plane, they have to be on <u>some</u> plane. There is a plane of any knowledge irrespective of the expertise level for those knowledge bubbles, everyone has to have a communication plane whether it is visual, mechanical, etc. There is a communication plane. In my estimation, you need to bring things that are similar, similar interfaces together to make things possible to grow. (BSIP1 personal communication transcript of video recording November 17, 2012).

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The model iterations were initially drawn using standard Mind Mapping software (MindManager by MindJet), then redrawn in Microsoft Office Word for ease of incorporation into documents for iterative review by the BSIP research participants.

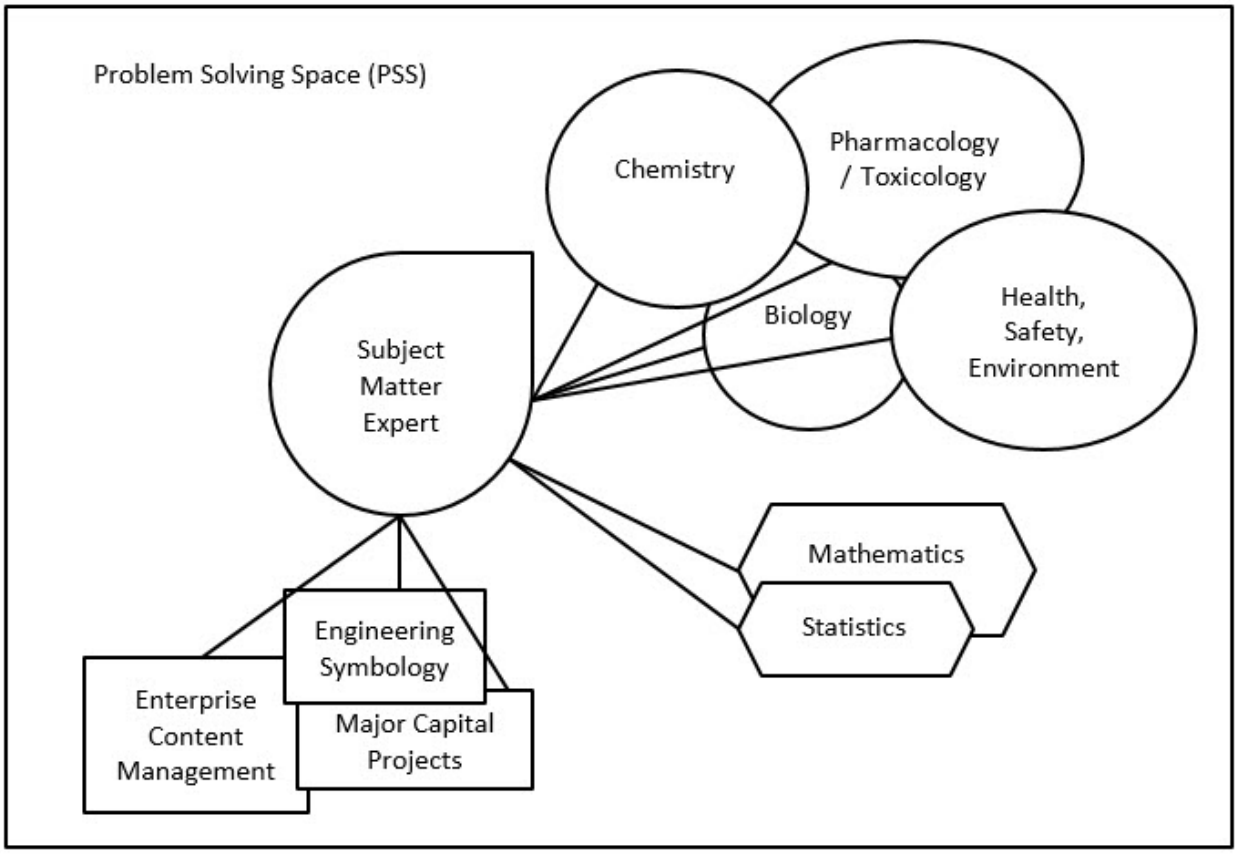

Figure 5. Model iteration 1: Re-representation of the individual boundary spanner-in-practice (BSIP) or subject matter expert (SME), their knowledge and experiential bases in the problem-solving space.

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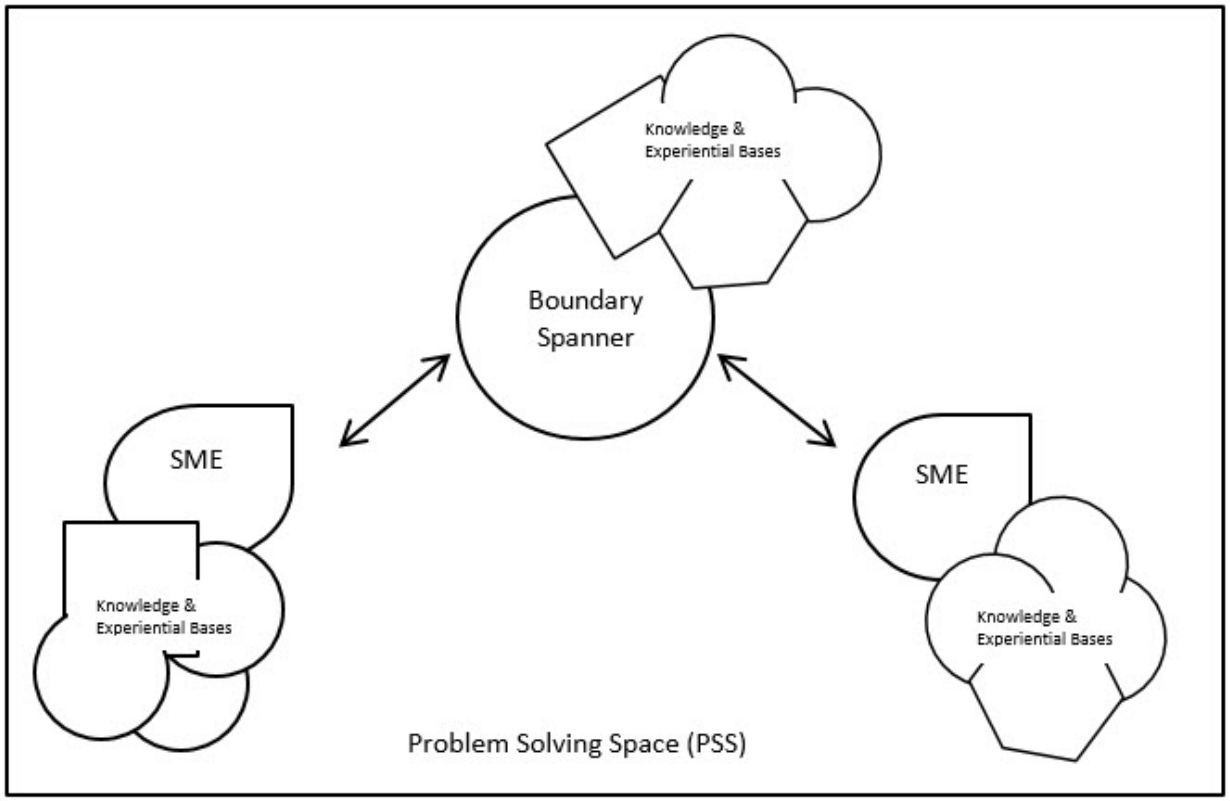

Figure 6. Model iteration 2: Boundary spanner-in-practice (BSIP) and two subject matter experts (SMEs). In model iteration 2, the drawing of the BSIP and the two SMEs were represented as being on the same plane, a communication plane.

Upon review, it was quickly agreed by all BSIPs that representation of multiple knowledge and experiential bases for a BSIP or SME and, in aggregate, from at least two SMEs and a Boundary Spanner in the problem-solving space (PSS) using Mind Mapping symbology becomes untenable quickly. BSIP4 remarked, upon retrospection, that the representations looked rather like strings of budding yeast cells. The resounding "no" from all BSIP research participants on both model iteration 1 and 2 offered an opportunity for further sense-making and analysis to better define what attributes should be incorporated into the model.

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A brief business analysis session ensued with the following attributes identified as “required” for incorporation into the informed model:

1. The number of boundaries representing Knowledge Bases (KB), Experiential Bases (EB), BSIP or SME, represented in the model or perceived, should be minimized.
2. Improved accessibility to the BSIP’s and SMEs’ KBs and EBs should be evident.

After these two general and high-level attributes were identified and agreed, BSIP1 drew a quick sketch on a yellow Post-It® Note. The sketch, below, resulted in quick agreement amongst the BSIP research participants as it met all required attributes.

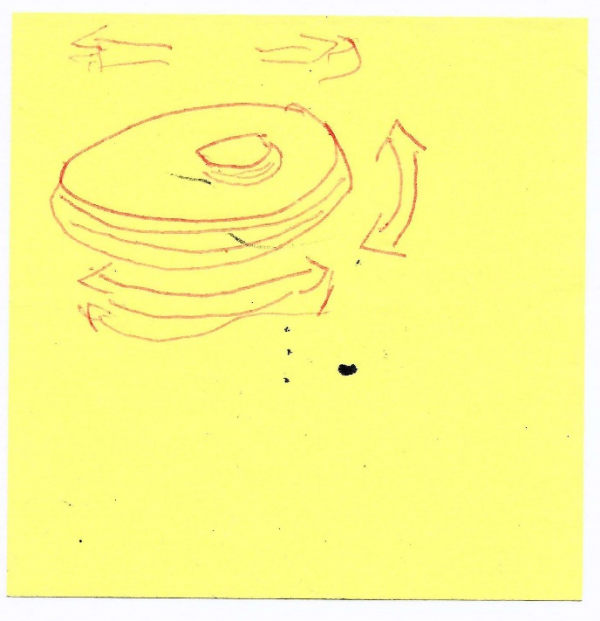

Figure 7. Sketch 1: Boundary spanner-in-practice (BSIP) or subject matter expert (SME).

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The sketch employs another standard model described by the BSIP research participants either as a stack of coins, the blades of a server in a RAID array (redundant array of independent disks), or records in a jukebox. The representation appeared to be scalable and thereby able to be employed to represent multiple simultaneous interactions of the single nondeterministic user model in the informed model in the PSS. As well, the network metaphor proved to be a highly integrative mechanism amongst the BSIP research participants that assisted in the BSIP research participants in mapping the social, organizational, and technological constructs integral to the foundational concepts of this research.

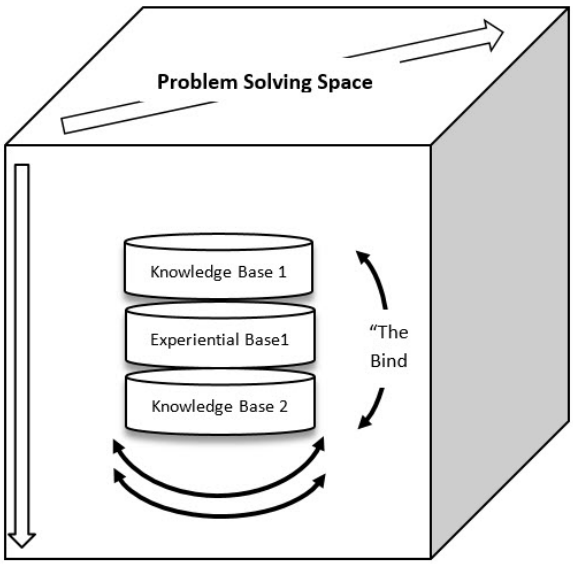

Figure 8. Model iteration 3: Re-rendering of sketch 1 representing a BSIP or SME.

The problem-solving space (PSS) is represented as the space within the cube. As the BSIPs discussed representing the boundaries as amorphous and permeable, the PSS was agreed as a cube to better render on a two-dimensional page. The two curved

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arrows running horizontal and parallel to each other at the bottom of sketch 1 and model iteration 3 represent the blending, building, and scaffolding of experiential and knowledge bases. The single curved arrow running vertically and spanning from KB1 to KB2, represent the binder or shared context in the PSS. BSIP1 offered some additional thoughts on how to represent the KBs and EBs that the contributing actors engaging in boundary spanning activities in the PSS are drawing on or sharing:

> *BSIP4: So when we're thinking about these binders, would that be… I kind of think of this as a knowledge base being pulled out from or pulled towards another SME. If you've got a BSIP and you have a couple of other SMEs that are working in this third dimension in the problem space, I really like this binder idea… For me, binders always remind me of bonds and that's a good thing. How are the binders going to be interacting within the confines of a SME or two SMEs and a boundary spanner? When I think about this, it's not just commonality because, as you said, there can be lots of commonality that people have. It might be language, it might be base knowledge of typical engineering experiences, it might be projects that they have been assigned to so they've got this shared context. But more to the point, its how can you bring these binders to bear so that the sum of the parts, and I don't want to be trite when I say this, but the sum of the parts is working together to build something beyond anything that any one of the individuals could do in this dimensional problem-solving space. That's the piece that I think from both the mechanics and the dynamics perspective that I would like to pursue a little bit. There are things that bind us together – we've worked together, we've got some similar, some similar, background. Certainly,*

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we can represent things together pretty well. From a SME expertise perspective though, I would probably have a much more difficult time as I don't know all the symbology for electrical or other engineering symbology that someone that does this every single day would know. The expertise is just not there. So from a binder perspective as far as mechanics, because I think of that as packet exchange, whether that's "here, I have a document for you and I've printed it off and I'm giving it to you" or "here's a URL and it's out in the SharePoint site"… that sort of exchange is important when you're trying to build up a knowledge base amongst what each other understands but I think what we've explored here today isn't just about the mechanics of stuff being exchanged, it's more about the dynamics as far as expertise and context; all that's the tacit side, the dynamic side of getting a SME or two and a BSIP together to work together. So from this binder perspective, I like that, because whether I'm talking about ionic bond or covalent bonds, it's all about binding things together. How do we bind the knowledge bases together? And that's the piece that I'm trying to pursue is "can you have some of these knowledge bases coming together and overlapping as a Venn diagram?" How would you, with all the modeling experience you bring to bear in this problem space, how would you see that binder represented? I understand it's difficult, even if you're doing a three-dimensional graphic, what do think, in your mind, these binding forces between a couple of SMEs and a BSIP look like based on what we've put together here? As a more three dimensional model of the single two dimensional model that we got from Copeland and

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O'Connor. For me we've got this pull that you see from covalent bonds when you have molecular forces pulling shells together.

BSIP1: Let me give it to you in a systems model that you might understand better. When you're looking at a relational model, what do you have between tables? You have indexes, or keys between tables. In the table itself there are different table elements and all you are doing is identifying the key indexes to relate things together so when you are looking at a schema, that key is your binder. So when you're talking about a solution, the table elements or the table expertise that's there can be individual and separate but it is all linked together by that key. So, if I'm putting a solution together and I need to get to elements within that table, I'm going thru that binder. Now how the tables interact is fluid….

BSIP4: That's the piece that I'm struggling with because there is such fluidity when you have true SMEs and a BSIP and the multiplicity of experiential learning and expertise that they bring to bear, that's the thing I have been struggling with because I don't see that fluidity when I'm looking at it from the binder perspective.

BSIP1: The thing is I may have the bind to bring those tables together so now I have the full extent of the tables available to me because I've got the binding relationship. If I'm doing a solution let's say that we have the bind is the

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knowledge in this third dimension. We've made the symbolic relationship – if I do this in this third dimension, the results will be this. Now in order to get it back into the solution world, I've got to take the symbolics and put it back into the preferred signs or preferred solution knowledge base that somebody else can interpret for the actual solution of the problem as opposed to the symbolics area. The symbolics may work within the team but in presenting the final solution it may have to be back in the context of…

BSIP4:…of the audience. If you as a team have presented it together, have come up with a solution that the mechanical and electrical engineers understand but now you have to present it to the guys on the construction site you are going to have to yet again re-represent it using symbology that they will understand…

BSIP1: …or the information at the level…like a construction person putting together a building doesn't need to know how that brick was constructed. They don't need to know how the concrete was made; they just need to know how to put it together. You give me the brick and the mortar and I know how to put it together, I know how to massage it together. I don't know the details behind it. So, it can be symbolic. But then, let's say that the solution going into an engineering base needs to be in their engineering terms; this is where the individual expertise that you have (in that space) has to contribute that (expertise) to the final solution in that format. So when we were talking about the

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key or the bind, I've brought these tables together and part of the solution has been that we needed to put these pieces together so the person that has expertise in that particular frame can say, "oh, what you're talking about is these key fields and here's what you need." So they contribute that part of the expertise but it is still part of a team solution. You do the solution and then you come back and present it in whatever format you need to. (BSIP1 personal communication transcript of video recording November 17, 2012).

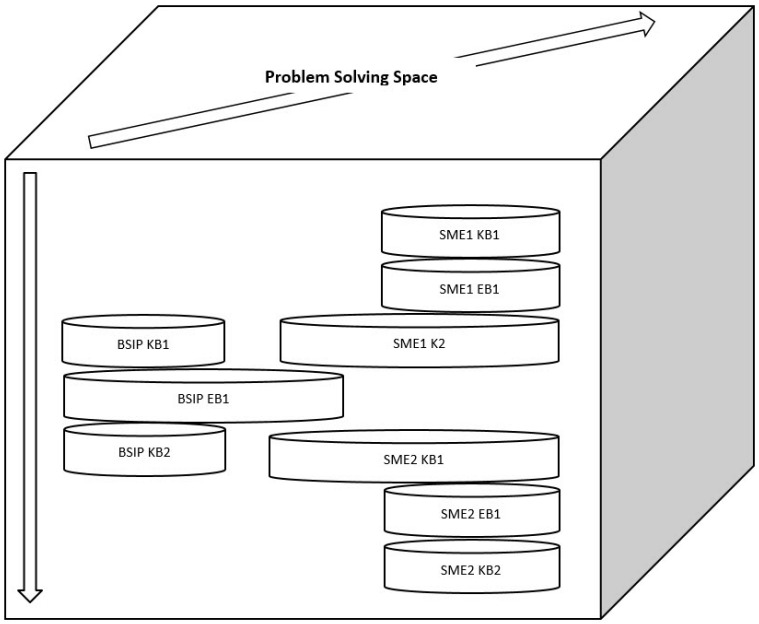

Figure 9. Model iteration 4: Boundary spanner-in-practice (BSIP) with subject matter expert 1 (SME1) and subject matter expert 2 (SME2) in the problem-solving space (PSS).

Model iteration 4 clearly showed scalability and simplicity of representation employing the new model for the BSIP and SMEs engaged in the PSS. As well, only one boundary, either real or perceived, must be crossed to access the BSIP's or SMEs' particular KBs and/or EBs. All research participants agreed that model iteration 4

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demonstrated improved accessibility to the KBs and EBs represented in association with either the BSIP or SMEs in the PSS.

The following conversation on model iteration 4 discussed the importance of the symbology in the representation:

> *BSIP4: ...the bind…and it's not only within an individual person but then it has to be extended to the small team. That's interesting….I like that. One of the things I really like about it being blades whether it's on a tractor and you're preparing the soil or whether it's blades in a server, I like the idea of the accessibility that, at least in my perspective, this model iteration brings to this. And from the chemist's perspective, I think about knowledge transfer as complete ionic exchange. Two people come together and they do a complete knowledge exchange on some aspect of the business and we see this all the time. A company buys another company – they have to become a new entity. There has to be a lot of knowledge transfer that goes on so that they can then become a new entity. Best of our practices go to you, best of your practices come to us; we come up with an entirely new entity based on that knowledge exchange, that knowledge transfer. The piece that I like about this is, and we've talked about this from the molecular perspective, I like the idea that when we put two more stacks, RAID arrays or whatever you want to think of them as, into this [third dimension in] the PSS when you put these folks together they are going to be pulling on different blades of each of those servers. The SME may have two or three or more areas that he or she is going to pull on and I see those circles extending*

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almost to the point of being elliptical like you think of in molecular bond theory because you have to have a large concentration of electrons [interaction] working in this PSS together with the BSIP and the SMEs working together. Because in molecular theory, you have to have that outer shell satisfied, "satisficed", and you're doing that by providing a solution, by providing input and expertise and knowledge, and so like the bonds, you have those outer shells satisfied. But there's a lot of activity right in those areas where the bonds are being shared. And I think that the <reconstructed> model can speak to that far more easily than the "kernel." I like that, that's a very good visual as to how we describe the individual model, the Copeland and O'Connor model, versus the one we're working on now. That's great, I really like that.

BSIP2: Thank you. The boundaries, that's one of the things that continues to be reflected throughout the body of research. Boundaries are important whether we're talking about physics, chemistry, when we get into human sciences because boundaries actually free each element to be itself because it defines it. In looking at the model that's drawn, there is again a sense of space. It's almost like a somewhat uniform space between those three objects, those three circles. But within that space there's also a sense of freedom, there's no gates, no doors to go through. The space is open, both over and underneath, above and below each one of these round discs. Well, with people, holding a business relationship, personal relationship, together, there's almost an invisible – well, you call it the bind – and I think of it as a bond - where there is a

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connectivity that occurs and the charge keeps the distance, maintains the distance.

BSIP4: That's interesting that you talk about that. Other BSIPs and I talked about that. There has to be enough bind, enough positive attraction, but you also see that if you get too close together then it starts repelling. So, it's almost this bond that you're talking about, it's how you set and maintain healthy boundaries and when you get past that, that's when you start seeing the dysfunction within the system whether it's in a team or a group or here, in the model, between the BS and some SMEs. That's an interesting way to look at it.

BSIP2: Thank you, it's an aspect that's missing many times in a lot of systems that are developed. They don't recognize, respect and plan for that space.

BSIP4: That's interesting to me because when I think about that from the molecular perspective, we've got a couple of options for bringing molecules together that typically don't want to come together, as you well know. We've got temperature, we can heat stuff up. Sometimes that's enough. Sometimes we can put pressure on the two components and that will be enough. Sometimes it's a combination of the two. And sometimes, there's such a difference that you actually have to use a catalyst. In my head, I see the BSIP as the catalyst bringing these two SMEs, or small teams or big teams together and lowering the

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energy of activation, because that's what we're talking about here, to bring these two groups, people, teams, whatever, together and actually see some positive things...happening as a part of what they do. They are supposed to be the catalyst. If they are supposed to be the catalyst, my question to you is: "Should their representation in this third dimension of the PSS look different in this space than the SMEs look like?" Right now, we have thought about this as they are all going to look like the blades of a server. We've got the bind going on between the SMEs and the BSIP. But if the BSIP has to be the catalyst, again, this is the chemist in me coming out, catalysts are very, very different than either of the two compounds that are coming together. So, do we need to readjust our thinking about how the BSIP is represented [in the model] in the third dimension of the PSS that we're creating?

BSIP2: If you want to have that uniform recognition when people look at the model, and there is going to be a difference in the role that each plays, then you would demonstrate that with a difference in symbols, in my mind.

BSIP4: OK! So, let's just play. Let's just look at this <the restructured individual model>, and if we have a couple of these – let's assume these are the SMEs – how would we better represent catalysts? When you think about BIO 101, which is typically where you introduce catalysts, they typically have a couple of puzzle pieces coming in, zooming in, and there is a third puzzle piece down below that the two puzzle pieces fit in to perfectly and when they come together

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with the catalyst piece, they also interlock themselves and then when they leave the catalyst they either represent the transformation by a different color combination or something. Is that something that we're going to need to represent in this model? Would it be wise for us to circle back around and think about this?

BSIP2: What I saw when you were saying that was an allergen. You know when you see the commercial of the allergen?

BSIP4: Right.

BSIP2: And it is a round sphere with many, many points all the way around it? And wherever that point touches, down the nasal cavity, down the throat, whatever, wherever that point touches, it stimulates. That's why the nose itches, the throat itches, the body releases secretions, and that begins to stimulate different kinds of circulation. And so, if you're going to have the knowledge disseminator, you have your two SMEs and your BSIP…that BSIP would need to be represented or demonstrated by an object or symbol that would be stimulating. Because every time that entity comes into the configuration and they are working within the system, something should happen! Hopefully, positive; always hopefully positive! But that's their role! That's actually their definition, that's what they do, that's who they are. So, they come into it and they stimulate it. And I guess you really wouldn't want to use an allergen because

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people don't normally see that as a positive! <chuckles> But I'm trying to demonstrate the object that I see, the design of the thing. It doesn't have to be that, it just needs to be something that represents that kind of dynamics.

BSIP4: OK, we'll have to circle back around and model [iteration 4] is going to have to include some different symbology so that we understand or at least can represent something like that within the context of the model. That's the piece that I have felt, as much as I have liked this one because it's more open, it allows me to work with the various knowledge bases that I'm representing in here as circles and extend them to look elliptically to look like orbitals that are integrating. But the piece that has bothered me is that putting three of these together in the PSS doesn't clearly represent what we're trying to in this. We've got a BSIP with very different attributes that they bring to the space that the other SMEs do not. (BSIP2 personal communication transcript of video recording January 20, 2013).

As the BSIP research participants reviewed and assessed model iteration 4, dialog ensued on how to represent the translation and negotiation resulting in the building of a new joint field between the two fields of practice – the co-jointly developed third dimension that is built between the two fields or *dimensions* provided by the SMEs each representing their small worlds that the boundary spanner works to bridge. As in Wilson's nested model of information behavior, not all activity undertaken in the PSS necessitates a BSIP to support development of an integrated framework. BSIPs are

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valuable when “reconciliation of meanings requires the contributing actors to “translate, negotiate, triangulate, and simplify in order to work together” (Star & Griesemer, 1989, p. 389). Upon reflection, BSIP4 printed model iteration 5 and quickly and simply drew a cloud around the interaction amongst and between the BSIP, SME1 and SME2 to represent the contributing actors engaging in boundary spanning activities. To BSIP4, the ‘cloud’ represented the third dimension in problem-solving which is achieved when the Boundary Spanner-in-Practice and two Subject Matter Experts each representing their respective small worlds bring their knowledge/experiential dimension to the problem-solving space thus resulting in the co-jointly developed third dimension in the problem-solving space. The technological metaphor again proved to be highly effective with the remaining BSIP research participants.

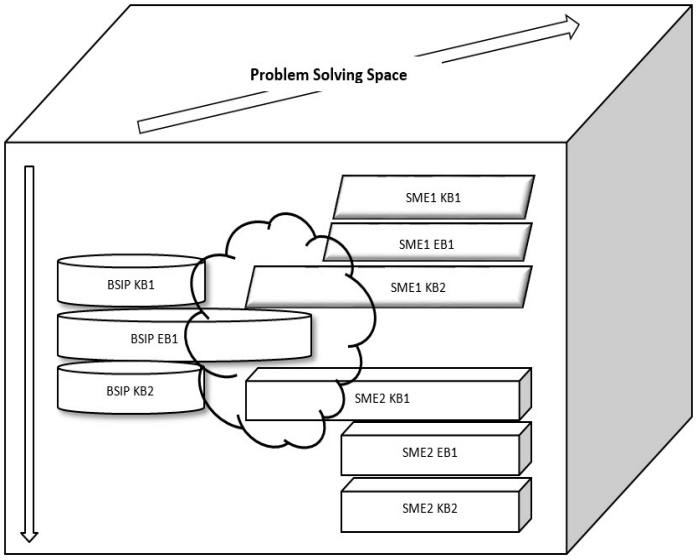

Figure 10. Model iteration 5: Contributing actors engaging in boundary spanning activities in the problem-solving space.

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With model iteration 5 agreed upon by the BSIP research participants, significant progress had been made on the research questions:

1. A model had been developed that demonstrated how the Copeland and O'Connor model changed in aggregate when multiple simultaneous interactions of the single nondeterministic user model were engaged during design activity.
2. The Copeland and O'Connor model was further informed to demonstrate the mechanics and dynamics in which boundary spanners-in-practice engaged with one or multiple small world Subject Matter Experts.

Next, the research participants would focus on further model refinement to represent expertise seeking behaviors and the physical and mental models constructed by boundary spanners during knowledge domain mapping. The initial plan was to develop a model that represented communication mechanics and dynamics in which the BSIP and SMEs engaged in the third dimension in the PSS. This model would then be integrated with a Knowledge Management (KM) Framework (Gibson & Cohen, 2003). The KM framework was developed using a standard Knowledge Pyramid as its foundation (Liebowitz, 1999, p. 5) which was then further informed by high-performing team dynamics (Liebowitz, 1999, p. 7; Katzenbach & Smith, 1993).

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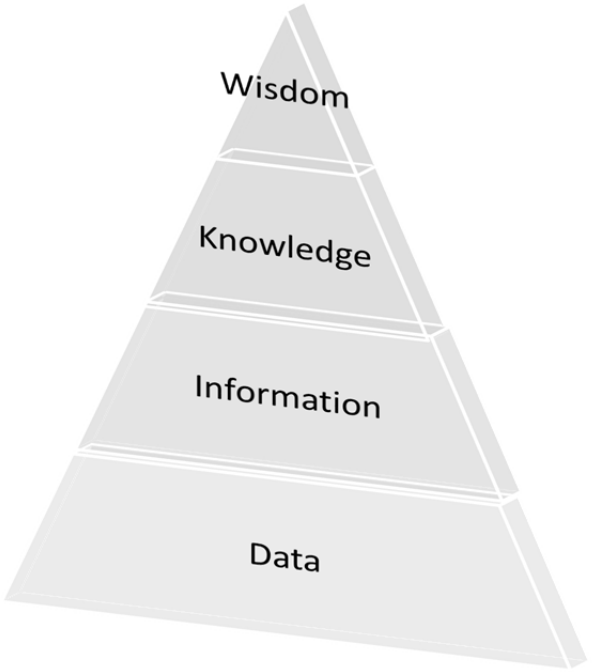

Figure 11. An example of a knowledge pyramid.

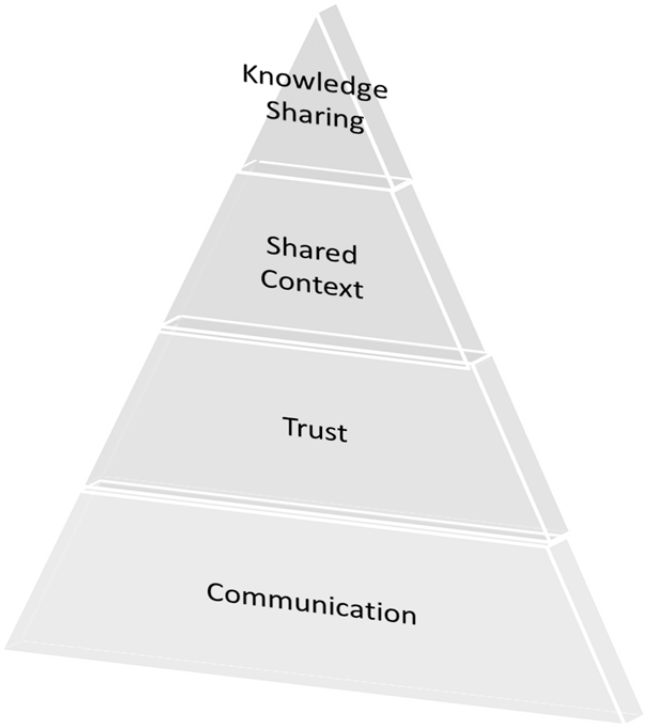

Figure 12. An example of a knowledge management framework.

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A conversation with BSIP3 started the development process for the communication model:

BSIP4: I'm not sure if the model needs to be representing both the mechanics and dynamics as part of the model; or does there need to be two models?

BSIP3: Well, I do believe it needs to be included. And I do believe it can be a single model that includes both dynamics and mechanics because both are factors in achieving the goals…. That's again where the BS needs to take the lead…because they are an interested third party but they are able to look at both the other entities from an outside view and try to discern what the differences are and work out a way to make things work. Now whether your variables such as the dynamics and mechanics of different languages, different cultures, the mechanics of how the communication is done whether it's email, IM or WebEx or whatever, if there's a language problem, OK, we need an interpreter. That's where WebEx would be very good.

BSIP4: Right.

BSIP3: For IM, when one can't read the other one's language, that's useless. So again, the BS is the one coordinating how information is transferred. Second, the information needs to be trustworthy. The communications need to

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be trustworthy. As you indicated, if you had a bad packet, that information is useless so it either needs to be re-transmitted or transmitted in a different form.

BSIP4: So that it gets there in a way that it isn't damaged.

BSIP3: I'm seeing this as a triangle. We have mechanics, dynamics and communication <points to each corner of a triangle> being the three outer boundaries of this triangle. Then the SMEs, with whatever symbology you choose for them, being in the bottom corners each and the BS in the top point because, again, they are working together in this space.

BSIP4: <I drew what was being described.> So, did I represent this correctly?

BSIP3: Actually, I was putting SMEs where you were putting mechanics, dynamics and communication. Within here <inside the larger triangle>, the BS, the SME <1> and SME <2> because they're working within that. That's how I envision it.

BSIP4: Umm hmm. <agreement>

BSIP3: Remaining within those boundaries, "the bind" connects those three. I see it as "the bind" or connectors…

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BSIP4: <drawing> Connectors like that?

BSIP3: Yeah, everything working together in harmony.

BSIP4: Yes, because this is the PSS, not the problem-failure space <chuckles>….

BSIP3: Yes, working together in harmony to solve the problem. Yes, even two sets of triangles is effective as you have there….

BSIP4: Yes, I just included the arrows.

BSIP3: What you have there, these would be your binds, these would be your connections or connectors. If you break a connection, you leak out <chuckles>…

BSIP4: It's interesting because the connection BSIP2 was saying in our previous conversation that we need to think about including some of the universal symbols for communication and that whether it's email, IM, cell phone, a head for face-to-face…

BSIP3: What I call face-time….

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BSIP4: I don't know what WebEx is – maybe the globe – those are all things that could then be represented within the confines of this to say when the connections are progressing as they should, then all of this should be working and heating up but when this doesn't work that's when the connectors start breaking.

BSIP3: Right.

BSIP4: And the connectors aren't just about the communication piece. Again, this is great because this connector could represent the communication connectors, but there is trust, there's shared context, there's, I don't know, environmental factors….there's any number of connectors….

BSIP3: Team work…

BSIP4: So, there's a lot of things that could be represented as connectors. So that if any one of those fails and a connector breaks this <the model> starts falling apart. And we can have these folks represented like that <symbology modification to indicate three different individuals, groups, etc.>

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BSIP3: or even a single one, a single server which is the embodiment of that component, the SME or the BS….And in the case of the triangle, I actually see that as a pyramid.

BSIP4: Ahhh. Very important, all my scribbles <laughs>. I'm going to have to re-render but that's ok, that helps a lot because then you can see...

BSIP3: Because we're talking about space here, we're not talking about a flat plane.

BSIP4: Well, that's one of the things that one of the BSIPs had said which caught me once I re-read the transcript – he had said "you have to be able to bring everybody into the same plane." And I'm not sure that that's really necessary. You need to bring them into the PSS but when I think of plane I think of 2D, flat.

BSIP3: X and Y

BSIP4: Yes and that's all, and I thought I'm not sure that that's really where we need to be.

BSIP3: Yeah, we put in the Z.

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BSIP4: So, with respect to the pyramid, we've got mechanics, dynamics and communication and then coming up <gestures to the pyramid peak>, is there a top point?

BSIP3: Mechanics, dynamics, communication is the top point.

BSIP4: So, we've got another one going back this way <gestures to foot of the pyramid>

BSIP3: Yeah….If you wanted to go 2D, this one would still do it. The peak actually creates the space so that would be the work space.

BSIP4: So the third dimension could be….

BSIP3: The actual work space.

BSIP4: Umm Hmm. Well, it certainly looks to be a pyramid like this.

BSIP3: And that way you have the different entities floating within that space working together to solve that problem. (BSIP3 personal communication transcript of video recording January 20, 2013).

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The conversation on the model refinement process continued with BSIP2:

BSIP2: What comes to mind on that, one of the biggest problems in any kind of project that's one with more than one person is passive-aggressiveness. And you know, people like you said, SME and BSIP2 are both smiling, everything is great…but what came into my mindscape when we were talking about that was the actual symbol for an email, the symbol for a cell phone, the simple symbols of communication. And you can demonstrate there's a stoppage here or a blockage there. Let's think of all the different dynamics, all the different measures with which people communicate, because one of the biggest red flags on a project, like a clogged up circulatory system, is the cessation of real communication. And in real communication, we are talking about the project, we are discussing the project, and we are building towards something <gestures like steps leading upwards towards a peak>. So, let's say you had a pyramid with stairs going up and on the stairs, it's really not a stagnant pyramid, it's almost like an escalator. Because you have communication – you have emails, you have cell phones, you have chats, webinars – you have all of that and everything is showing that this is like liquid, this is not a solid, it has to be a liquid, it's fluid…it's moving. <hands moving up and down>

When that stagnates or stops, the project, the project team is in trouble. And so, how would you demonstrate that in a model? Well, you'd have to use Universal Recognizable symbols, all of which have to do with communication. One would actually be face-to-face, another would be email. Many of us today

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are computer literate and so we recognize those universal signs, symbols that represent communication. So, that would be one way to demonstrate in the model. Avoidance is another way…you talk about resistance.

BSIP4: Yes, those are things that from an attribute perspective, you can measure the Ohms of resistance in an electrical circuit.

BSIP2: You can measure it in a people circuit, too. Resistance comes from not returning emails, not returning calls, missing meetings, all of those things are measurable. So that begins to let you know, this whole human factor is off-kilter here. (BSIP2 personal communication transcript of video recording January 20, 2013).

Capture and vetting of the consolidated feedback on the next refinement of the informed model resulted in model iteration 6. Upon consideration of utilizing the vector symbology rather than the "network style" representation for the BSIP and SMEs resulted in our discarding model iteration 6 for model iteration 7.

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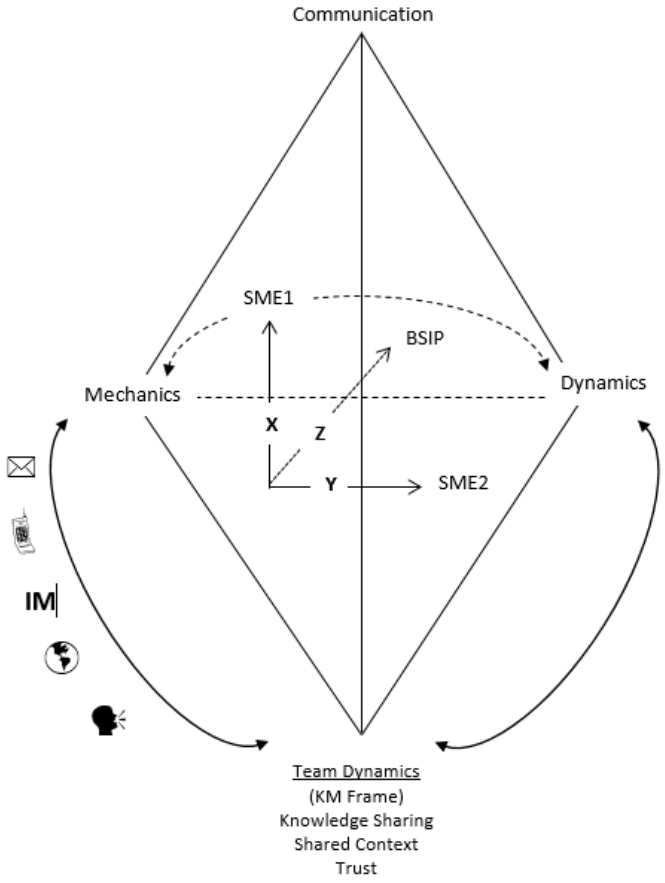

Figure 13. Model iteration 6: Boundary spanner-in-practice (BSIP) with subject matter expert 1 (SME1) and subject matter expert 2 (SME2) in the communication pyramid.

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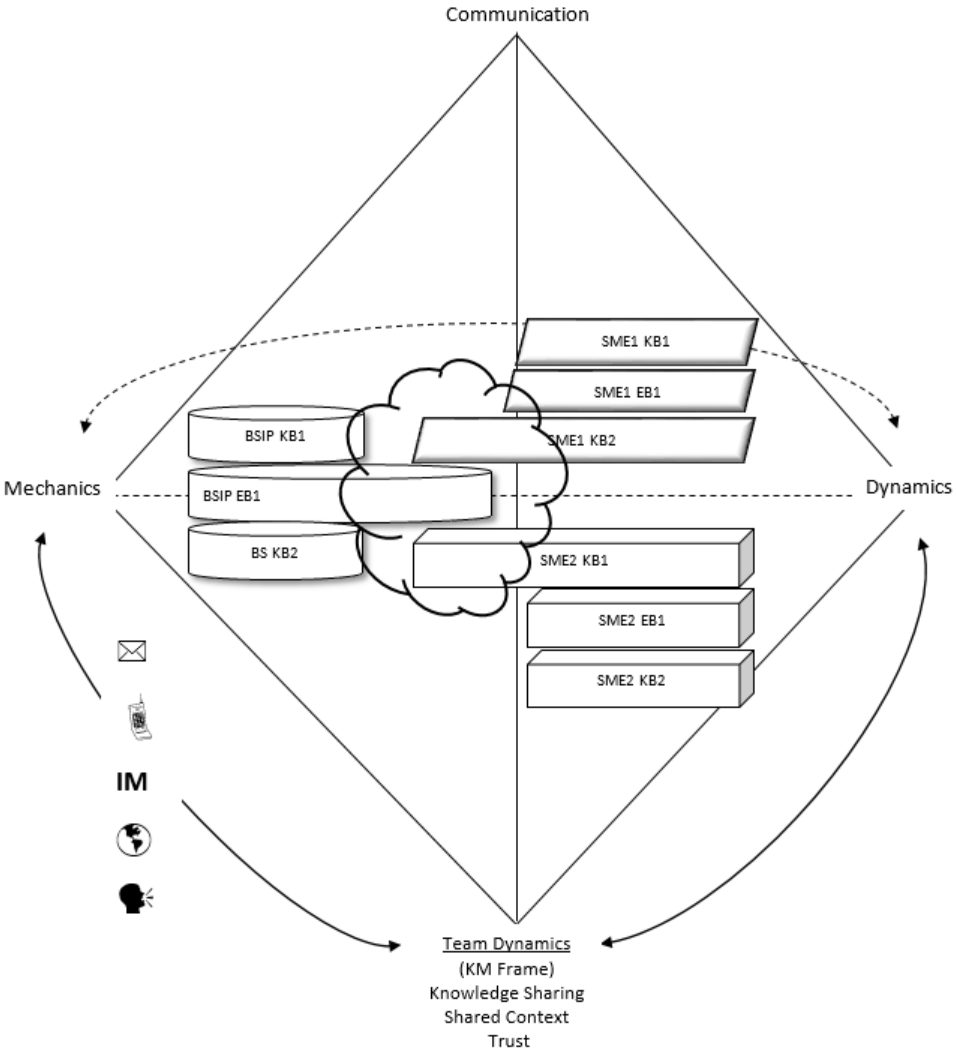

Figure 14. Model iteration 7: Contributing actors engaging in boundary spanning activities in the problem-solving space in the communication pyramid framework.

Model iteration 7 received a warmer response from all BSIP research participants. However, upon reflection, the BSIP research participants believed that this model could be construed as confusing to the uninitiated. As well, none of the BSIP participants could develop a way to map communication mechanics and dynamics to the knowledge boundaries represented in the Knowledge Management Framework.

At this point, the BSIP participants reviewed Carlile's Integrative Framework (2004) to assess if it would be more appropriate to utilize Shannon and Weaver's (1949)

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three levels of communication complexity - syntactic, semantic and pragmatic - associated with each knowledge boundary for incorporation into the next model iteration.

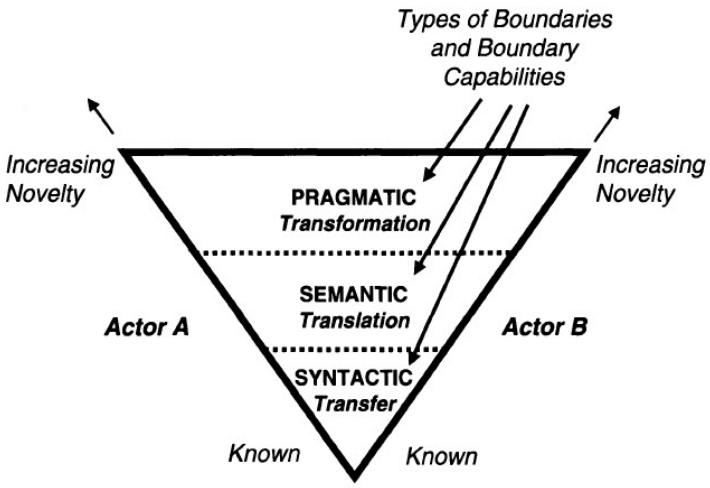

Figure 15. An integrated/3-T framework for managing knowledge across boundaries. Adapted from "Transferring, translating, and transforming: an integrative framework for managing knowledge across boundaries," by P. R. Carlile, 2004, Organization Science, (15)5, p. 558. Copyright 2004 by INFORMS.

To recap, as differences in the amount or type of domain-specific knowledge increase between actors, the communication effort required to share and assess each other's domain-specific knowledge increases.

- At Syntactic or Information Processing Boundaries, knowledge processing or transfer occurs requiring stable conditions and a common vocabulary to begin the process of developing a common knowledge base.
- At Semantic or Interpretive Boundaries, knowledge translation occurs. Knowledge translation must be initiated when novelty presents differences and dependencies that are either unclear or ambiguous.

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- At Pragmatic or Political Boundaries, knowledge transformation occurs. When novelty presents results to actors that have differences, the dependencies between the actors are not indifferent requiring negotiation and knowledge transformation to pursue common goals through the creation of “joint fields.” At a pragmatic boundaries, actors must be able to represent current and more novel forms of knowledge, understand their consequences, and transform their domain-specific knowledge accordingly. This transformed knowledge creates a joint field and is both valuable and determined to be of consequence given the novelty of the solution/problem-solving space.

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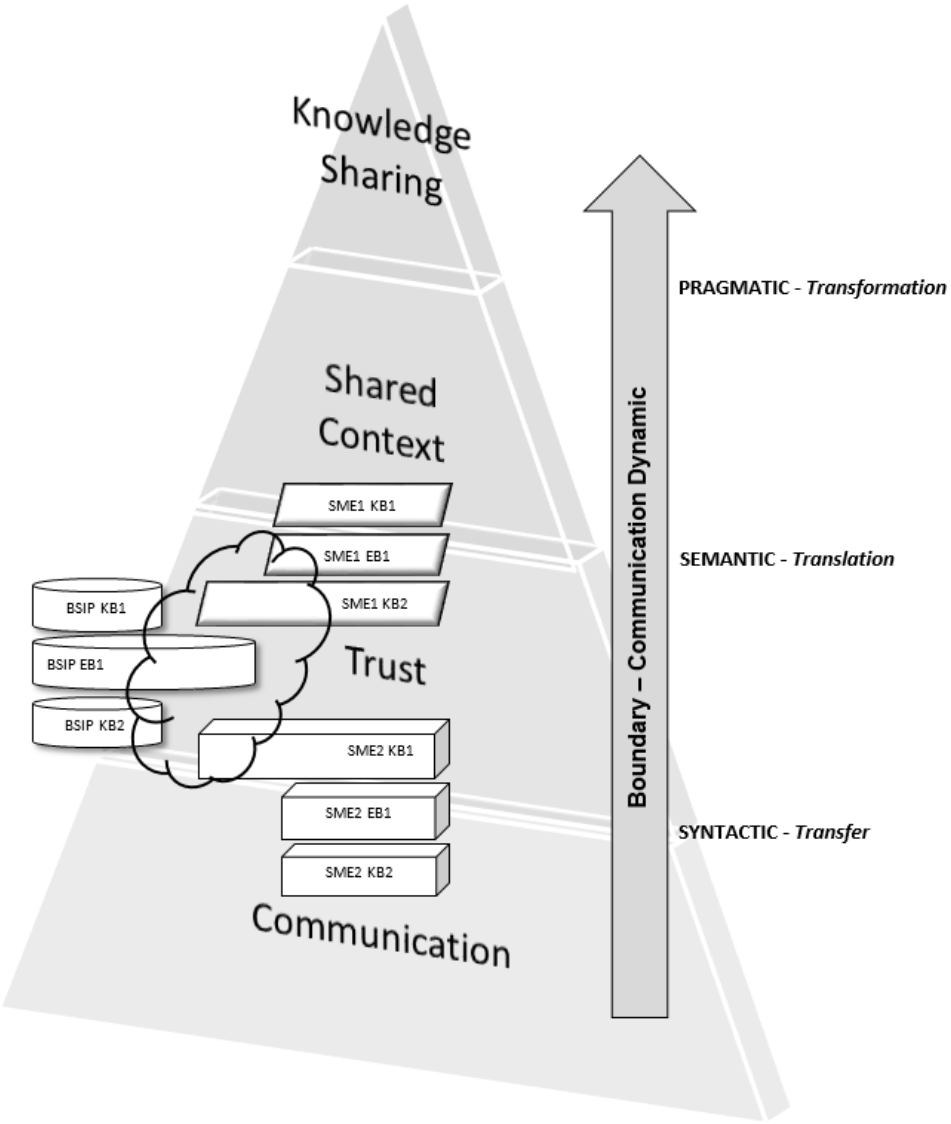

Figure 16. Model iteration 8: Contributing actors engaging in boundary spanning activities in the problem-solving space in the knowledge management framework.

In model iteration 8, Carlile's integrative framework, which associates the three levels of communication complexity with each knowledge boundary, was overlaid as an arrow on a standard knowledge management (KM) framework (Gibson & Cohen, 2003) informed by high-performing team dynamics. (Katzenbach & Smith, 1993). In model iteration 8, the KM Framework became the foundation for the integration of the

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contributing actors engaging in boundary spanning activities in the problem-solving space. The base for the KM Framework is communication; communication complexity increases with each knowledge boundary requiring the BSIP to demonstrate proficiency with the competency framework (Williams, 2002) as a BSIP as well as negotiating the boundaries and issues faced by their global team members (Espinosa et. al., 2003).

Model iteration 8 was well received by all BSIP research participants and spurred an additional model iteration for consideration.

Model iteration 9 posed the KM framework as the savannah or plain. This was done purposely to clearly communicate the "level-playing field" required described so well by BSIP1:

> *BSIP1: …Even in drawing this model, the SMEs have to be on the same plane, they have to be on some plane. There is a plane of any knowledge irrespective of the expertise level for those knowledge bubbles, everyone has to have a communication plane whether it is visual, mechanical, etc. There is a communication plane. In my estimation, you need to bring things that are similar, similar interfaces together to make things possible to grow. (BSIP1 personal communication transcript of video recording November 17, 2012).*

In model iteration 9, the KM framework is reconfigured into a matrix format rather than a hierarchical configuration used in model iteration 8. This iteration was employed with trust as the central enabler to communication, shared context and knowledge sharing. This representation works well for organizations that are heavily matrixed and

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use puzzle pieces, stars, cycle diagrams, etc. to represent/describe functions or programs within their business segments.

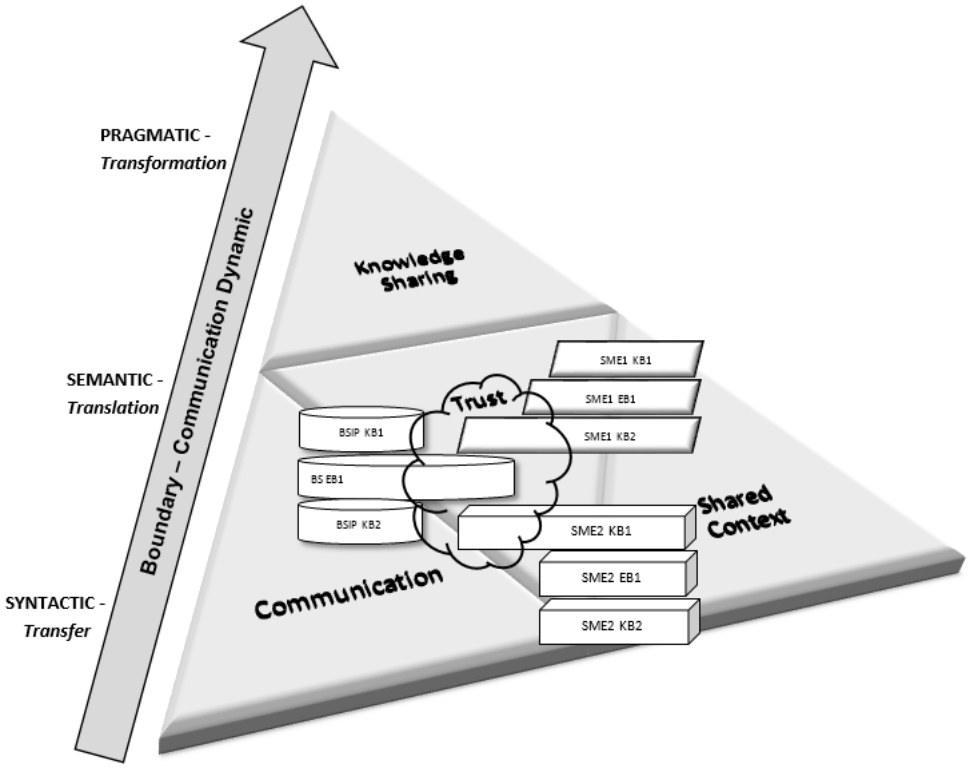

Figure 17. Model iteration 9: Contributing actors engaging in boundary spanning activities in the problem-solving space on the knowledge management (KM) framework 'savannah.'

With model iterations 8 and 9 agreed upon by the BSIP research participants, the final research question was considered to have been fully addressed. The BSIP research participants had developed two model iterations representing expertise seeking behaviors and the physical and mental models constructed by boundary spanners during knowledge domain mapping.

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CONTINUING RESEARCH

TESTING FOR USEFULNESS AND VALIDATION

Once the informed model was developed and the integrative framework agreed, the BSIP Research Participants began the process of testing the output of the research process for usefulness in their respective organizations that cross multiple business segments in Oil and Industry, Financial Services, Consultancies and the Academy. This has included presentations to knowledge managers and organizational facilitators on the role of 'Boundary Spanner-in-Practice', organizational opportunities leveraging their skillset, and the proposed models for contributing actors in the problem-solving space at the organizational, functional, and project level. At the present time and dependent on the organization, data collection has proceeded for eighteen months to more than two years and includes email messages and/or short videos of presentation participants' reactions. As this is still the early stage of data collection, analysis of the participant feedback is currently identifying plus/delta and critiques for the role, responsibilities and competencies for the BSIP as well as the models, especially model iteration 5 (Contributing actors engaging in boundary spanning activities in the problem-solving space) and model iterations 8 and 9 (Contributing actors engaging in boundary spanning activities in the problem-solving space in the knowledge management framework or on the savannah).

This grass-roots effort has evoked the most interest and penetration of the BSIP title and testing of the role at the project and functional level in those organizations actively engaged in some aspect of knowledge management - those employing knowledge managers or knowledge workers (i.e., information stewards, information

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custodians, digital engineers, data quality managers, etc.). The integration of boundary spanning activities in the problem-solving space with the team dynamics framework, which many of the knowledge managers viewed as their organization's knowledge management foundation or framework, immediately led to the question, "What other frameworks can be integrated into the boundary spanning and team dynamics framework?"

Two organizational frameworks were initially identified for testing - the operational excellence framework and the functional excellence framework. Operational excellence is the systematic management of risk factors to achieve and sustain a high level of performance utilizing a standard approach to prevent incidents by identifying, managing and mitigating risks thereby improving reliability across an organization. Within this context, tenets of operation are typically developed with corresponding metrics thus providing a framework for continuous improvement to demonstrate on-going risk mitigation and performance improvement. The following illustration depicts typical focus areas for an organization:

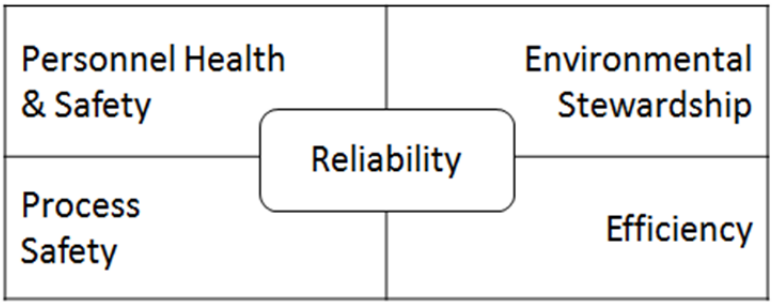

Figure 18. An example of operational excellence focus areas.

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A functional excellence framework (FEF) applies the organization's operational excellence framework to a particular business segment, division, or function (information technology, engineering disciplines, etc.). Development of a functional excellence framework follows the same process as that used in developing the operational excellence framework for the organization. Strategic objectives are identified, execution focus item(s) are developed for each strategic objective, and metrics and milestones are identified to demonstrate progress towards meeting each objective. Focus items in a FEF tie far more closely to the business segment or function that developed them while falling into three or four general categories: create business value, maintain cost discipline, drive functional excellence, etc. The following illustration depicts a generic FEF for an organization:

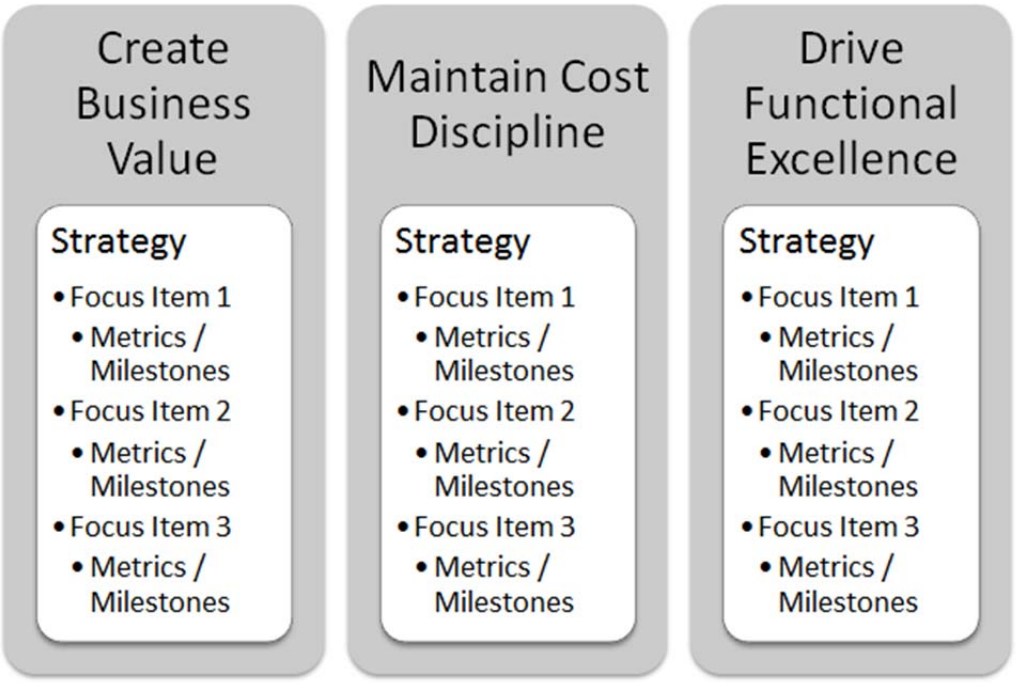

Figure 19. An example of a generic functional excellence framework.

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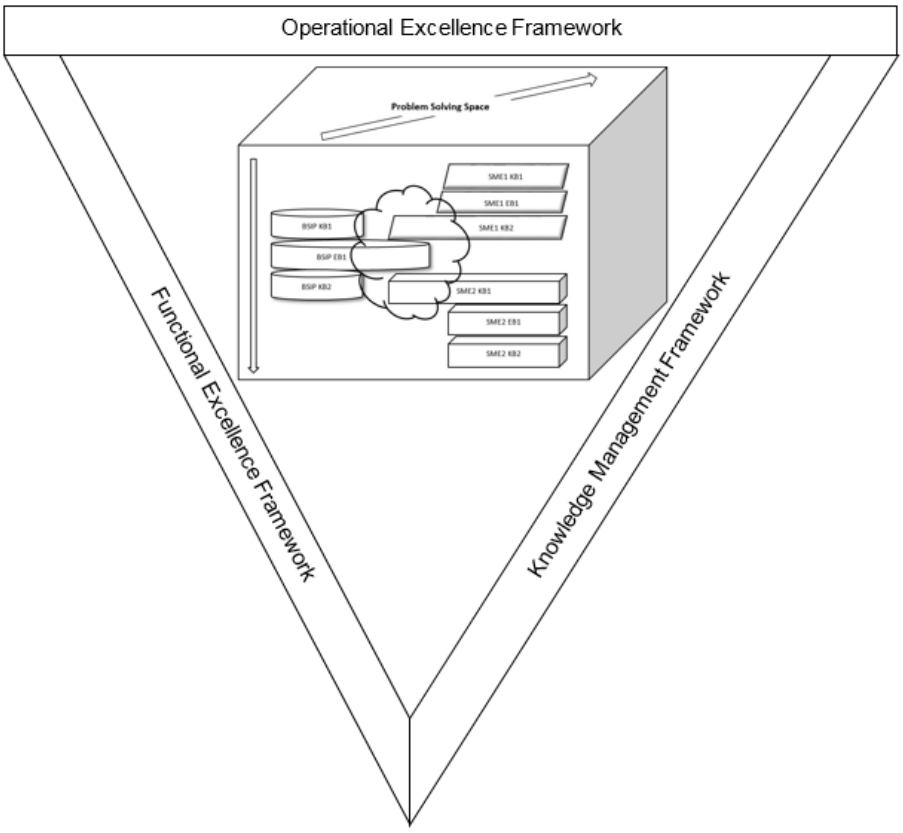

Figure 20. Integration of an operational excellence framework, a knowledge management framework and boundary spanning activities in the problem-solving space.

While the graphical representation of additional integrated framework(s) with that of boundary spanning activities in the PSS continues to progress, it is the recognition that the integration of this model and a knowledge management framework can be leveraged to further integration of other organizational frameworks that is important. This work has begun to raise the visibility and importance of utilizing BSIPs to embed aspects of the organization's knowledge management framework into operational and functional excellence frameworks. As well, this may offer opportunities for longitudinal alignment of organizational functional excellence frameworks unrealized heretofore.

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CONCLUSION AND FUTURE RESEARCH

The goal of this research was to further inform and refine the Copeland and O'Connor Nondeterministic Model of Engineering Design Activity, adapted from Copeland (O'Connor, Copeland, & Kearns, 2003, p. 141), bringing the foundations of information philosophy (Wilson, 1977, 1983; Chatman, 1991, 1998) to the conduct of complex knowledge work. This model resulted from examination by Copeland and O'Connor of engineering design activity but was developed to explain design activity at the level of a single nondeterministic user – an engineer, a bounty hunter, and a submarine chaser. The research undertaken addressed the following questions:

- How can the model be further informed to address the mechanics and dynamics in which boundary spanners-in-practice (BSIP) engage with one or multiple small world Subject Matter Experts?
    - How does the model change in aggregate when multiple simultaneous interactions of the single nondeterministic user model engage during design activity?
    - How can the model represent expertise seeking behaviors and the physical and mental models constructed by boundary spanners during knowledge domain mapping?

As an outcome of this research, a model has been developed that demonstrates how the Copeland and O'Connor model changes in aggregate when multiple simultaneous interactions of the single nondeterministic user model were engaged during design activity. In addition, the Copeland and O'Connor model was further informed to demonstrate the mechanics and dynamics in which boundary spanners-in-

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practice engaged with one or multiple small world subject matter experts. Lastly, two model iterations were developed representing expertise seeking behaviors and the physical and mental models constructed by boundary spanners during knowledge domain mapping.

A possible future study which presented from the "zigzag process" of data collection, comparison and analysis was identification of trust as a precondition for communication, shared context and knowledge sharing between and amongst the BSIP and SME small world representatives.

In Williams' competency framework for boundary spanners, four major competencies are identified that BSIPs must develop to be successful. The first competency - building sustainable relationships – includes the skill trustworthiness which is defined as the ability to demonstrate reliability, deliver on promises, and deal fairly and honestly to build and sustain relationships. Each of the BSIP research participants spoke about trust as an element of their work:

> *BSIP2: "It seems that the first aspect was all about building a trust factor. And that that would be very important relative to communication because people will only extend themselves as far as they feel safe, secure and can trust. …everyone is going to have equal worth, equal trust, equal respect and, hopefully, equal impact, equal input."*

> *BSIP3: For IM, when one can't read the other one's language, that's useless. So again, the BSIP is the one coordinating how information is*

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transferred. Second, the information needs to be trustworthy. The communications need to be trustworthy. As you indicated, if you had a bad packet, that information is useless so it either needs to be re-transmitted or transmitted in a different form.

BSIP 4: "And the connectors aren't just about the communication piece... this connector could represent the communication connectors, but there is trust, there's shared context, there's, I don't know, environmental factors….there's any number of connectors….

BSIP3: Team work…"

In addition, in model iteration 9, the KM framework was reconfigured into a matrix format rather than the hierarchical configuration used in model iteration 8 in which communication forms the base of the pyramid followed by trust, shared context, and knowledge sharing at the apex. Model iteration 9 was specifically developed with trust as the central enabler to communication, shared context and knowledge sharing in response to feedback received while testing for usefulness of the models. In essence, it has been posited that without development of trust first, effective communication, shared context and knowledge sharing will not ensue prohibiting boundary spanning and knowledge processing, translation and transformation.

These observations suggest future studies including:

- How do BSIPs facilitate trust?

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- How can trust be operationalized by contributing actors engaging in boundary spanning activities in the problem-solving space?

The more informed models developed as an outcome of this research may be more broadly applicable to those industries which employ large numbers of knowledge workers including engineering, the library and academia, Knowledge Management practitioners, etc. By identifying the enablers required to successfully develop cross-industry practices and domain expertise, BSIPs can become the crucial bridges to support corporate changes in strategy and direction. Lastly, in the engineering space, numerous opportunities continue to utilize a model that integrates expertise development, BSIPs and boundary spanning through already established frameworks or programs including business/operational excellence, functional excellence frameworks, continuous improvement, organization development, learning and development, information management, social networks and media, business process improvement, etc.

Both the current research and suggested projects will continue to add to the practice of knowledge management, production of new joint fields, new knowledge domains or entirely new knowledge bases.

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APPENDIX A

BOUNDARY SPANNER-IN-PRACTICE (BSIP) RESEARCH PARTICIPANT LEVEL-SETTING PRE-VIDEOTAPE

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Appendix A: Boundary Spanner-in-Practice (BSIP) Research Participant Level-Setting Pre-Videotape

1. [START VIDEO]: We are going to be discussing a topic I am researching for my dissertation and we will be video-taping this conversation. Do I have your permission to videotape it? [WAIT FOR RESPONSE] I will now minimize the video display so it will not be distracting to our conversation.
2. As stated previously, you were selected as a participant for this research project because you have performed the work typical of a boundary spanner-in-practice either previously in your career or are a boundary spanner-in-practice in your present role. Do you agree to participate in this research project? [WAIT FOR RESPONSE]
3. We can take a stretch break and bio break as necessary. I expect that this session will span 60 – 90 minutes so plan on at least one break during this time. I have water and a large comfy chair ready for you!
4. I will be asking each boundary spanner-in-practice the same questions. There is no right or wrong answer. I am simply interested in your perspective on boundary spanning and how we can better inform the Copeland and O'Connor Nondeterministic Model of Engineering.
5. I have been assessing how the Copeland and O'Connor Nondeterministic Model of Engineering Design Activity would change if you were not looking at the Problem Solving Space (PSS) from the perspective of a single individual working in this space but rather from the perspective of a group of individuals.

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Specifically, the space would be occupied by a boundary spanner and two Subject Matter Experts.

6. We will be discussing the types of work boundary spanners-in-practice perform and how that work impacts and informs the process of model revision. I will provide you with a transcript of our conversations. Today, I would like to work with you to gain your perspective on the model we have developed, so far.

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APPENDIX B

OPEN-ENDED QUESTIONS POSED TO BOUNDARY SPANNER-IN-PRACTICE (BSIP) RESEARCH PARTICIPANTS

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Appendix B: Open-ended Questions Posed to Boundary Spanner-in-Practice (BSIP) Research Participants

1. What were your initial impressions of the Copeland and O'Connor Nondeterministic Model of Engineering Design Activity?
2. What pluses and deltas do you see in the Copeland and O'Connor model?
3. How might you consider modifying the Copeland and O'Connor model to maximize the pluses while minimizing the deltas?
4. What symbols representing communication mechanics and dynamics could be used to further inform and clarify the model?

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APPENDIX C

INTERVIEW WITH BOUNDARY SPANNER-IN-PRACTICE (BSIP) RL

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Appendix C

Interview with Boundary Spanner-in-Practice (BSIP) RL

November 17, 2012

RL – When I looked at the model the first time, I was envisioning multiple similar types of SMEs – multiple engineers from different disciplines but with certain amounts of commonality – math background, problem-solving background, the approach of breaking things down into components… things that are similar within disciplines. But then you have some things that are different, including experiences that they bring to bear. I have experience in oil and gas engineering, or mechanical engineering, electrical engineering that someone else does not have even though they have electrical engineering background – their experience is different; they may have power and electronics experience.

KLL: So it would be similar base knowledge (of an engineering discipline) but different experiential knowledge.

RL: What I was envisioning in the model, was that you basically had different layers that different SMEs could bring to bear in the problem solving space.

KLL: As I was working on my proposal, I tried to imagine how can you represent information exchanged from the molecular model perspective? In the case of complete Knowledge transfer, it can be modeled as an ionic exchange. Catalysts - How can you model information exchanged if SMEs don't want to or know how to work together/interact in a positive way? So it takes a catalyst to bring…

RL: ***- some sort of reaction together.***

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KLL: Another thing that I really like about our discussions is that with my math background and your engineering background, I think sometimes it is important to have an understanding of other symbology whether it's engineering or chemistry or biology - how to represent communication or work in another way to help people communicate and understand what you are trying to explain. What are we doing here? Making little diagrams so that we can understand the base (O'Connor/Copeland) model which "seems/appears" to be more of a "let's peel back the onion." If we can get a better grip on the mechanics of communication, which might be just transferring explicit content to help inform and bring people to a more knowledgeable state from the SMEs perspective that the boundary spanner may know exists but one or the other SMEs do not. A representative mind map/bubble diagram or Venn diagram is insufficient to help people understand how the multiple knowledge bases that individual SMEs have within themselves can be brought to bear in the problem-solving space.

RL: (Refers to one of the diagrams drawn during the session with a BS and the SMEs) Even in drawing this model, the SMEs have to be on the same plane, they have to be on some plane. There is a plane of any knowledge irrespective of the expertise level for those knowledge bubbles, everyone has to have a communication plane whether it is visual, mechanical, etc. There is a communication plane. In my estimation, you need to bring things that are similar, similar interfaces together to make things possible to grow.

I can give you an example: We were solving a problem in mechanical engineering and I applied electrical engineering because it formed, to me, an easier visual to solve it. So, I was solving a mechanical engineering problem with electrical

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engineering terms. When you are representing a systematic problem to someone that is not a systems person, you have to find a correlation of something modeling the same situation so they can understand it. You've heard people explain things like this many times, "it's sort of like if you're doing this" and it has nothing to do with the system or what you are talking about but it is a representation that they can grasp. Once they grasp the concept, now they may have input because now they have a base in that area to help solve the problem. So, if I understand it, it's like this; it's a similarity but it's in a different environment. So, sometimes you can solve problems in one environment using knowledge base for another environment. So when I was looking at this layer (O'Connor/Copeland model), I was looking at similar disciplines or similar things that are in common and then binding them together with what they have in common, common math, maybe common technical terms, maybe the expertise of solving complex problems.

In the other example, where you are calling on different SMEs with completely different types of skills, the skills themselves can be interrelated because they are still part of the, call it, natural science base. We have applied science differently but some of the laws, whether electricity or mechanical or whatever, those laws are still the same.

KLL: That's interesting because from a taxonomy perspective, all of this is about communication. How can you come up with a similar taxonomy. As you've seen from the proposal, we talk about hierarchical/taxonomy terms. If you can come up with a hierarchy or a symbology, some representation whether it's taxonomic, symbolic, whether it's more complex and actually allows you to communicate with language skills. All of this has to be brought to bear because the current model seems to be

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insufficiently robust to be able to talk about both the mechanics and dynamics of communication because there is a lot of communication mechanics that takes place between the boundary spanner and SME(s).

One of the things that I think is really helpful in O'Connor's book when they start talking about the model, it's not just having good communication, having a good communication model; it's even about how a BS knows how to ask questions and what kinds of questions and question states people can use to both bring SMEs who do not have feet in both areas but how can you ask questions that pull them into the problem-solving space and have them want to help you work on the problem. Especially in corporations, you get assigned to a particular problem solving space, you may bring language barriers etc. You need a BS that can work with all those pieces so you actually make forward progress in the problem-solving space. Can we look at a way to develop the enhanced model to represent the BS and SME interaction. If we took a look at the enhanced model, it could be described as stacked blades in a server. Looking at it from a molecular perspective, if you look at the rings as stacked knowledge bases that comprise a single SMEs knowledge space, the individual's inventory of k bases. If you are pulling on your complete array of k bases, a SME may have more or less k acquisition activity in particular areas in which they are engaging.

RL: I called this the binder between all the different layers. What binds everything together is the **assumption** that the SMEs and BS are all geared towards solving the problem. This must be the common assumption. Then you have other things that can be considered binders – you've worked together before in the past or you have certain other fundamental commonalities. In some cases, it's not the lack of fundamental

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commonalities, it's the communication process itself. Communicating – if two people are interested in communicating, they will find things that are in common. If one person is trying to be dominant, the other person has an interaction - either they will accept the dominance or there will be a conflict. You can also observe body language to help understand the acceptance of the situation. Then you get into semantics – one person's understanding of something being "acceptable," the word "acceptable" may have different meanings as well. You need similar communication styles and communication interpretations.

There is environmental space that impacts this as well. In a noisy environment, they may not hear the entire concept. That may result in partiality as they only picked up pieces. This might not allow the team to hear in an impartial way which will impact the whole space. They may have to act on incomplete information. There are many things in the environment that impact communication. If I have historical information – commonality because you have worked together previously – you may work together differently as compared to people that have never worked together. Perceptions in the space: An engineer may look at things differently than a chemist to start off with but once you start peeling back the onion, you start putting into a common term even though it's not the same space for both of them, the understanding can improve and they can actually solve problems in a third dimension as opposed to the dimension that each one of them is in.

KLL: You bring a dimension, the SMEs bring a dimension. But the actual problem solving space – that's where you actually go into a third dimension because they each bring their own dimension based on their individual knowledge bases – a

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space in which each brings their dimension to the problem-solving space which becomes the 3-dimensional problem solving space.

RL: Because you are in this 3rd dimension, there are points that are intersecting, that are in common, maybe not specifically the same information but similar. The points can be intersecting, perhaps not quite in common, but similar. You are able to build a 3rd model, which is basically a compromise model, in which their understanding is similar.

KLL: Noisy environments; too many times when you are in problem solving space, you don't really take time to identify what people consider to be valuable vs. noise? That's what I tried to represent in the proposal in the k gaps charts. How much of the noise is due to directed problem solving versus noise produced from communication dynamics and mechanics as part of the development of shared understanding. Some of the noise in the PSS comes from the development of common understanding especially in the context of historical information – team members that have worked together previously. Team members with a history – who have already developed shared understanding or context - reduce the noise that comes from the team building process (storming, norming, etc.).

You can set some of the queries aside in the 3-d PSS that are part of the development of trust and shared context. When you bring new SMEs into the problem-solving space, is there a way to get past the positioning – who brings what to bear in this space, identifying their experience – and engaging in a directed manner to solve a problem if you don't know the depth and breadth of their experience.

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RL: You are talking about interference noise – I'm talking about noise that may be preventing someone to seek or understand. It may be not interaction noise but noise from impact of experiences.

Let me give you an example that might help:

I was brought in to a situation with a group of experts that were trying to problem solve. They had very directed presentations on the problem and they did an information share for over an hour. Once they were through, they asked me now that you have seen the problem, do you have any way to solve it? And it was all noise. It was noise because my need for information was at a different level than what they were presenting at. Their presentation was based on their own space, on their own concept of what the problem was. We all understood what the problem was but we were at different levels for the approach. What they were presenting as an opportunity was in their space, not in a problem space or level in which I could interact with completely. I understood their space, I understood their problem – but there was noise from a conceptual basis. Once I approached it within a different framework, I was able to bring information that ultimately resolved the problem. It's not necessarily confrontational noise, it may be body language or semantics; someone is reading something that's not there or visualizing/approaching something that really isn't accurate or necessarily there – that's a different type of noise. Many times when you are trying to communicate with people – have a serious conversation - in a very noisy place, we may take different outlooks from it. Yet if we were in a sports arena versus a dance hall versus a church environment there are different environmental factors that come into play. Interactions using the same words would be taken differently.

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KLL: So the context brings different interpretations to bear…

RL: Right! So when you have different SMEs/people that are trying to work together in an environment, if one is experiencing physical pain or something else, their reception will be less - which is another environmental factor. So when I was talking about the "bind" that brings everybody together – the "bind" is the thing that basically works for everybody. In other words, I need to be pain-free in order to interact with you so *you need to get me to that state*. That's the binding that we have. If I'm a different discipline, the "bind" may be that I need to understand how to present a problem in a context that you can understand it or another discipline can understand it. That's the third dimension – everyone understands it. If it's the words, the semantics, the words may be the bind – I need to find semantics that we both agree upon so that we have positive interactions.

I had an engineer that never went to school, never got an engineering degree. All his engineering capability and understanding came from just having done the work; some of it doesn't have to be expertise but rather common sense and how you approach the situation. And yet he was able to, without having the equations or technical expertise, perform engineering functions, and sometimes even better than an actual engineer just by having had the experience or the conceptual.

We were talking about cutting wood. Over time, people have learned how to interact with the wood, how to make certain cuts, how to make it give them the maximum strength for bonding. If you took somebody that had never worked with wood, and didn't appreciate the quality of the wood or the grain, they may do it differently and it would compromise the bond because the wood going cross-grain is not going to be as

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strong as the when the grain is going the same direction. So some of it, you do the same procedures, the same cuts, the same processes, but it has to be brought more into a space where you understand all the variables that you need to control.

KLL: So let's relate this back to this engineer who hadn't gone through formal training, the way you have and the way most engineers today are trained. How would they be able to represent variables if they hadn't learned the symbology associated with engineering? Would they learn this through on-the-job training as a journeyman apprentice? Help me understand - I'm curious about this person because, as you can imagine, that's totally beyond my context. I don't know of anyone that's in the engineering space that has come up this way. How would a person that doesn't have the same set of knowledge bases that someone that would have gone through, say, the formal education process - how would they be developing the sorts of expected knowledge bases that a person in that capacity would have or should have?

RL: Mathematics doesn't necessarily need to be there for an engineer. Math is around us at all points – even if you are baking a cake, there still is a point at which you do a fixed measurement of some sort and some of those are fairly physical. He was aware of those. A barrel is a barrel, an atom is an atom, and electrical current is a current. There were certain measurements that he became aware of just by having been there, involved in the process. How you assemble all that knowledge together to perform an engineering task – that's the part that he was never taught and became innate for him. Some of it was probably trial by error-type scenarios and things did or didn't work and that became part of his knowledge base. The more complex things became, the more he had to pull from his line of experiences that build up to that type of

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thing. And there were certain things that he was not going to be able to accomplish. He probably had a limit because of not having formal training but a lot of the more basic stuff he could do as well as any other engineer.

KLL: So, he had to be extremely bright if he had learned as much about engineering as he had without typical standard formal higher education-type training. So would you say that he was certainly capable of learning the various mathematical equations? Would you say that he was proficient in both the mathematical symbology and the engineering symbology? Or were there gaps?

RL: There were gaps but he had filled some of the gaps that he had had in the past. If someone had taken the time to explain to him, “here are some equations or here are some processes,” he was capable of picking those processes up.

KLL: So let’s relate this back to this 3-d PSS. We’ve got you, the BS, and a SME (SME #1), truly an expert in his own right because of his innate understanding of engineering and, because of his experience, having done any number of engineering activities that he had been successful at whether there was math or other symbology that he needed to know or not, he was a successful engineer. He brought expertise to bear in the PSS. How would you have worked with him with, say, another SME (SME #2) to solve a problem which he (SME #1) might have been unable to solve by himself and, perhaps, would have been difficult for a trained engineer (SME #2, with formal higher education training and experiential learning as an engineer working in the field)? How would you have worked with them - knowing you, as BS, were bringing these two SMEs, with very dissimilar expertise/experiential bases, together to work as a threesome on a difficult problem in the Problem Solving Space?

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RL: Because somebody has been in a trained environment doesn't necessarily make them a better engineer.

KLL: That's true; the piece that's very critical in an engineering capacity is the ability to apply common sense.

RL: The one brought experience base and application base. The other one may not have had similar application base but may have had the technical base to solve some of the more complex or the less aware parts of the problem that needed to be solved. The practical engineer may have taken a lesser success or accomplishment….

KLL: And that just the concept of "satisficing" again; it doesn't have to be perfect. All it has to do is work.

RL: Right! If the goal was for the operation to do "X" and it did "X", then one may accept it accomplished the goal. On the other hand, the other person may say it accomplished the goal but if we did this much more, it would be likely that it would last this much longer.

KL: Would you think that one or the other SME would not be able to pursue that kind of a solution…. better solution, not perfect solution, better solution - based on their experiential base? Think back to a time that you were working with this person and someone else. Or would they simply take a different tack?

RL: They would take a different approach to solving the problem.

KLL: What if they had presented both of those different solutions to you, as BS. How would you help them see - sometimes if you develop a solution yourself, sometimes it's very hard to see a solution beyond your context, acknowledging that someone else has developed a better solution. Sometimes, it becomes somewhat

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personal. Might there have been something like that? How would you have handled that?

RL: I have always taken the tack that the more complex the problem is, then you need to approach the solution in at least three different ways. Normally, the first solution is the more common path that most people would take or appears to be the clearest solution or way to solve the problem. The second solution should not borrow from the first; it needs to be a completely different solution. It should normally be a completely different path with a few similarities but maybe not. By the time that you look to create a third entirely different solution; if you are able to, then you probably should look for a fourth. There may come a point where you say, I can't think of anything different. At this point, your last and final solution will borrow from all your previous solutions and normally you may find a more perfect solution by combining aspects of all the previous solutions. So, to answer your previous question, somebody bringing a different perspective - if you have already exhausted your other solutions – there may be bits and pieces or maybe the entirety of the solution that they're bringing, you should be able to see either extreme benefits or that it is not going to be worth considering. My experience has shown me how certain solutions have come to bear. I have had many, many experiences where without having gone to the second or third or fourth solution we would have come up with an inferior solution, something that would have worked, but that was not the best solution. Maybe not the simplest, less cost effective or whatever other measures you want to use on it. I think that having multiple approaches, having three different SMEs that have different frameworks to approach a problem,

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there may be some solutions that come to bear that independently would not have been there because of a different approach.

In the example I gave earlier, solving a mechanical engineering problem using electrical engineering expertise - the electrical model was very apparent to everybody that the solution that had been presented in the mechanical model would never work. But in the mechanical model it appeared to be more complex, even for mechanical engineers, as they had created the solution initially and yet in a different space it became very apparent that this is not solving the problem.

KLL: Was it because of the representation that it looked more complex in the mechanical space as compared to the electrical space? Or was it because there were more variables that they were attempting to bring to bear in the mechanical space than the electrical space? Help me understand why it was more complex in the mechanical space than the solution appeared to be perhaps untenable as compared to representing it in the electrical space?

RL: Let me answer that in two ways. One, my assumption was that the mechanical engineer that had originally proposed it was fully capable and as such, his expertise would have been such that when he's looking at a solution just like I look at a solution in my space and can really see something that looks like it's going to work or not then he would have had that same expertise. If he did, then the representation, the way he was approaching it, must have been more complex and made it not as clear-cut. In my context, the information was presented in an entirely different format and it stood out clearer. The clarity of it stood out.

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KLL: So it was the representation of the solution being more clear-cut. Would you say that there was less noise?

RL: Yes.

KLL: Why?

RL: The information, in presenting it in a mechanical format, was a context that everybody was familiar with. They basically had a resolution to equations or an approach that had been standardized. On my side, it was a difference of an entirely different look to the same problem so the expectations were not the same. People had to look at the problem differently. Because at first they had to see the representation in a different format so when they saw the solution, it was like "oh, ok, I see it differently." And you've seen it in a lot of things, too. Where somebody talks about it in their space and somebody else looks at it and says, "well, why don't you just do this" and, boom, the problem is solved differently.

KLL: So did all the people that were looking at the solution, from first the mechanical and then the electrical perspective, two contexts for the same problem – were they expecting it to come out as a representation within the mechanical engineering space and was it a surprise that it could be represented in a very different space, the electrical space, and that was what helped them bring this clearer vision because the electrical space obviously gave them a better cleaner understanding of what the problem was and how to solve it? And the other question I have is, if you are representing it in that different a way, were the people that it was being presented to, all SMEs in their own right, could they see and understand what was being represented in both the mechanical space and electrical space and that's why when it was presented in

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the electrical space they said, “oh, much easier, much better, we understand this, we can do this.”

RL: The problem was the mechanical solution had been implemented and it had failed to generate the results they were looking for. In looking at the solution that they had proposed - and I represented in a different format - it became crystal clear to them why the mechanical solution had failed. It was not apparent in the original solution. It had been presented to different mechanical engineering functions and even higher level functions and they had all agreed via the approval process. When they saw it in the electrical format, they all said, “oh, we missed something here.”

KLL: So who was the catalyst in taking the solution which had been represented in the mechanical space and re-representing the problem in the electrical space and then re-presenting it to the SMEs that had to both understand that there was a solution at hand, a better solution at hand, and then it had to be run up through the various approving authorities to actually implement the solution because it was a much better solution than what the mechanical solution represented. Because if you already have a solution, but it’s not a very good solution, but it is a solution, there still has to be a catalyst to take the problem and re-represent it and says that there is a better way to do it.

RL: The situation was that they had come to me to answer why it had failed. I took the studies that they had done in mechanical and it was apparent to me, looking at some of the mechanical parts of it that they had not really solved the problem. Not because it actually had occurred that way but in the approach to the problem but there seemed to be a missing piece here so I searched putting the problem together in a

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different context – again, you are solving a problem with different scenarios. I took it in my context and said let's solve it in a different way.

KLL: So was it different input or different variables you had to use to re-represent the problem in a better way? You had ingested all the information that they had presented in this problem space. What did you specifically bring to bear that they had been unable to bring to bear from an expertise perspective?

RL: The different modeling. In the modeling - all the parameters had to be converted. In other words, what you see as flow parameters in mechanical engineering had to be represented as current or resistance or in one case parallel circuitry and the translation is easy from the standpoint if you understand the mechanics or you understand the science you are able to take some of that and translate it and say, this is essentially the same thing. The current was the flow; the pressure was the resistance.

KLL: So a lot of that becomes not just taxonomy, it actually requires translation of the variables from one format as far as representation to another. So again, we've got this, the dynamics of communication or in this instance it is the dynamics of translation of symbology so that the communication can go from the mechanics in the mechanical engineering space to the mechanics in the electrical engineering space. Is that correct?

RL: Correct. Now, I know for sure that it could have been represented in the mechanical space, probably in a different format that would have brought the same conclusion.

KLL: So, when you're talking format, though, would that just be the symbology that's required for mechanical engineering vs. electrical engineering?

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RL: Correct. It may even be if you were looking it from a systems perspective, when you're looking at nodals, and you're saying that I have these different nodes of communication, it could have been represented in a different format that somebody in a communications major might say "oh, that's clear cut." So electrical was simply a different way to represent it. And the mechanical was not as obvious. Once I had represented it in electrical, the mechanical people looked at it and said, "yeah, we see it." And they could see it in a mechanical format.

KLL: So they also had enough understanding of the symbology and realized that when the variables were translated from mechanical space to the electrical space, they also saw that there was a better solution that was provided so then they also bought in on this, yes?

RL: Correct. The translation was presented to them; in other words, their understanding of fluid flow and the translation into electrical, that had to be communicated to where they understood that but once they understood that, it looked like a clear cut model for them. They were able to grasp it. So again, there was a translation involved and they were able to see it but again it was put into a perspective getting back to where they understood it.

KLL: Putting it into a context…

RL: your third space…

KLL: this problem dimension… so that they would have an understanding and a context that they could embrace the solution within the confines of their expertise.

RL: Correct, because it was not literally an electrical problem or electrical representation, it was electrical symbolism I used. In other words, I didn't go in there

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and say, “ok, the resistance is 10k Ohms and the current is so many Amps.” It’s just, you have current 1, current 2, resistance 1, resistance 2 and you were building the resistance of…so, it was your third dimension. It was just like when you and I talked about math - when you’re baking a cake; cake is equal to the sum of all these different ingredients….so much flour, sugar, butter, so many process steps, whatever you have to do…bake it to make it and that’s white cake. If I’m going to make chocolate, I can add chocolate to both sides of the equation and now I might have to do it in the right order but I’ve added chocolate to both sides and now I’ve got chocolate cake. It’s a mathematical representation yet to somebody it’s more of a symbolic representation of how I make a cake, it’s not a mathematical model. It’s just symbolic of how I do things. So some of it is performance-based and some of it is just how you model it. So that’s why I say, that sometimes when you have interaction you’re looking at the symbolism of the information so that at a point or a level, that all people can be on the same page. That’s what I call the “binder” that basically means, what do we have in common? We’re given brain power, is it mathematical knowledge? Is it systems knowledge? Is it science knowledge? Communication - same language?

KLL: So when we’re thinking about these binders, would that be… I kind of think of this as a knowledge base being pulled out from or pulled towards another SME. If you’ve got a BS and you have a couple of other SMEs that are working in this 3-d problem space, I really like this binder idea… For me, binders always remind me of bonds and that’s a good thing. How are the binders going to be interacting within the confines of a SME or two SMEs and a boundary spanner? When I think about this, it’s not just commonality because, as you said, there can be lots of commonality that people

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have. It might be language, it might be base knowledge of typical engineering experiences, it might be projects that they have been assigned to so they've got this shared context. But more to the point, it's how can you bring these binders to bear so that the sum of the parts, and I don't want to be trite when I say this, but the sum of the parts is working together to build something beyond anything that any one of the individuals could do in this dimensional problem solving space. That's the piece that I think from both the mechanics and the dynamics perspective that I would like to pursue a little bit. There are things that bind us together – we've worked together, we've got some similar, *some similar*, background. Certainly, we can represent things together pretty well. From a SME expertise perspective though, I would probably have a much more difficult time as I don't know all the symbology for electrical or other engineering symbology that someone that does this every single day would know. The expertise is just not there. So from a binder perspective as far as mechanics, because I think of that as packet exchange, whether that's "here, I have a document for you and I've printed it off and I'm giving it to you" or "here's a URL and it's out in the SharePoint site"… that sort of exchange is important when you're trying to build up a knowledge base amongst what each other understands but I think what we've explored here today isn't just about the mechanics of stuff being exchanged, it's more about the dynamics as far as expertise and context; all that's the tacit side, the dynamic side of getting a SME or two and a BS together to work together. So from this binder perspective, I like that, because whether I'm talking about ionic bond or covalent bonds, it's all about binding things together. How do we bind the knowledge bases together? And that's the piece that I'm trying to pursue is "can you have some of these knowledge bases coming together and

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overlapping as a Venn diagram?" How would you, with all the modeling experience you bring to bear in this problem space, how would you see that binder represented? I understand it's difficult, even if you're doing a 3-d graphic, what do think, in your mind, these binding forces between a couple of SMEs and a BS look like based on what we've put together here as a more 3-d model of the single 2-d model that we got from Copeland and O'Connor. For me we've got this pull that you see from covalent bonds when you have molecular forces pulling shells together.

RL: Let me give it to you in a systems model that you might understand better. When you're looking at a relational model, what do you have between tables? You have indexes, or keys between tables. In the table itself there are different table elements and all you are doing is identifying the key indexes to relate things together so when you are looking at a schema, that key is your binder. So when you're talking about a solution, the table elements or the table expertise that's there can be individual and separate but it is all linked together by that key. So, if I'm putting a solution together and I need to get to elements within that table, I'm going thru that binder. Now how the tables interact is fluid….

KLL: That's the piece that I'm struggling with because there is such fluidity when you have true SMEs and a BS and the multiplicity of experiential learning and expertise that they bring to bear, that's the thing I have been struggling with because I don't see that fluidity when I'm looking at it from the binder perspective.

RL: The thing is I may have the bind to bring those tables together so now I have the full extent of the tables available to me because I've got the binding relationship. If I'm doing a solution let's say that we have the bind is the knowledge in this third

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dimension. We've made the symbolic relationship – if I do this in this third dimension, the results will be this. Now in order to get it back into the solution world, I've got to take the symbolics and put it back into the preferred signs or preferred solution knowledge base that somebody else can interpret for the actual solution of the problem as opposed to the symbolics area. The symbolics may work within the team but in presenting the final solution it may have to be back in the context of…

KLL: …of the audience. If you as a team have presented it together, have come up with a solution that the mechanical and electrical engineers understand but now you have to present it to the guys on the construction site you are going to have to yet again re-represent it using symbology that they will understand…

RL: …or the information at the level…like a construction person putting together a building doesn't need to know how that brick was constructed. They don't need to know how the concrete was made; they just need to know how to put it together. You give me the brick and the mortar and I know how to put it together, I know how to massage it together. I don't know the details behind it. So, it can be symbolic. But then, let's say that the solution going into an engineering base needs to be in their engineering terms; this is where the individual expertise that you have (in that space) has to contribute that (expertise) to the final solution in that format. So when we were talking about the key or the bind, I've brought these tables together and part of the solution has been that we needed to put these pieces together so the person that has expertise in that particular frame can say, "oh, what you're talking about is these key fields and here's what you need." So they contribute that part of the expertise but it is

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still part of a team solution. You do the solution and then you come back and present it in whatever format you need to.

There was a class that I took in college a long time ago that was called Machine Science and it was the solutions of machine space in multidimensional space. They would take a solution and machine was just a word for a group of functions that were together and they would represent those functions mathematically. The solutions were actually in multidimensional space which were mathematically related but they were not related to anything physical that you or I had ever seen in 3-d so it was imaginary space, it was vector space. But when a solution came back it was a solution of a machine that basically said here is a group of solutions to perform this function or activity that you were looking at as a group. And so somewhere in there your solution was there but it had to be represented back in the physical world but it had used imaginary space to put it together. So the relationships were still valid it was just that you had a family of solutions as opposed to a single solution. But you could pick from the family of solutions, now you had a space which you could draw a solution from that you would never had if you hadn't gotten back into the other area. The other area is either other expertise or systems or processes that are exterior to your solution but they help narrow down maybe what your solutions are. May be a different way to look at it, too.

End of Interview Transcript for BSIP1 RL

Interviewer's Notes Captured during Interview with BSIP1 RL

November 17, 2012

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Noise can be both interference but can also prevent SMEs to see or understand. Not interaction noise but even from past experiences. The need for information was different than the SMEs need for information – SME RL was at a different level. They were maximizing an opportunity for a need for a solution but the noise was coming from a conceptual solution.

The environment may bring noise – physical noise – to the interaction and the context can bring different interpretations to bear on the communication. Even physical context for a SME can bring other contexts and interpretations to bear.

How can I bring the context to each SME so everyone can understand it and work productively in the problem dimensional space?

Common sense and experience brought better solutions than a trained engineer. People learn how to interact in the problem space.

Innate or trial by error learning developed the engineer's knowledge base. There were more limiting tasks.

Application of engineering principles is critical to the success of an engineer. Come up with three different solutions. Path 1 is always the most direct path. The second should be a completely different solution. The third solution should be again dissimilar to the first two. The last solution will be a blend of some of the first – you have exhausted the solutions when you can no longer come up with new and innovative solutions to a problem. You are looking for solutions that will work but out of all of these you need to identify the best one. The more different frameworks to approach a problem

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will help to identify solutions or expertise can be brought to bear because of the individual approaches.

Binder – what do I have in common? Systems knowledge

Keys between tables. And there are individual elements and key indexes to relate the elements together. The key is the binder. The table elements are separate but they are linked together by the key. I can link the elements.

I have the full extent of the tables available to me.

Interviewer's Observations during Interview with BSIP1 RL

November 17, 2012

Disparity of modeling tools for engineering vs. communication (mechanics and dynamics). Dynamics tools resemble "sticks and stones" when compared to the robust and elegant tools available to the engineering community. Difficult to engender interest from the engineering community in research, modeling when there is such a gap in symbology, tools, etc. Hard for someone that typically works in the engineering space to place credence in the models or conclusions drawn from them. This must be a future focus area.

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APPENDIX D

INTERVIEW WITH BOUNDARY SPANNER-IN-PRACTICE (BSIP) VC

JANUARY 20, 2013

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Appendix D

Interview with Boundary Spanner-in-Practice (BSIP) VC

January 20, 2013

Part 1:

KL: We have been talking about my areas of interest with respect to my dissertation. This BSIP brings/comes with a myriad of expertise. I just want to go through the level setting discussion with my first Delphi participant. We're going to have a relaxed conversation about a topic that I'm researching for my dissertation. I have been assessing how the Copeland and O'Connor Non-Deterministic Model of Engineering Design Activity could change if we were not looking at the Problem Solving Space (PSS) from the perspective of a single individual working in this space but rather with a small team of individuals. Specifically, we'd be looking at the space occupied by a boundary spanner and two Subject Matter Experts (SMEs) so a very small team.

I have been working with BSIPs to begin the process of model revision and we have some of their thoughts, drawings, to help you understand where we've been in our conversations. I've given you a transcript of our videotaped conversation; that way, you have some perspective of where we've been, the path that we're following.

So today, it's your turn! Your turn to give us your perspective on the work we've done so far. I've selected you to review the work we've completed so far because I believe that you have performed work typical of boundary spanners in the multiple careers that you've held either previously or in the current role that you have. I will be asking you some questions; we'll be talking a little bit about the papers and the

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transcript from BSIP1. We're just going to have a conversation about "what do you think about the model so far?" What are its plusses and minuses? I'm going to be referring to the transcript myself to make sure that we stay on track because I think there are some specific areas that would be interesting for us to explore. There are no right or wrong answers to any of the questions; I'm just looking for your perspective. I'm looking for your input and feedback specifically on the model because we're really trying, in this dissertation, to move it from an individual model of engineering and take it to a team aspect. We're also looking at the design activities with respect to communication; the mechanics of communication and the dynamics of communication and how that might impact model development. Do we need one model? Do we need two models? Should the model even demonstrate what we think might be impact with the mechanics of communication vs. the dynamics? So, those are things we are going to talk about. We can take a stretch break, and a bio break as necessary. I expect that we'll be talking 60 – 90 minutes so we'll plan for at least one stretch break. Water, comfy chair, whatever you need.

VC: This looks great!

KL: So, in my dissertation proposal you saw the Non-Deterministic Model of Engineering Design Activity and it talks about the PSS but I think the thing that was really impactful for me was this is obviously something that a particular person was doing. It's a model that I think is worthy of further research so that we can use it from a team-building perspective. And I think some of the perspectives that you have on teams, human communication in a safe environment, setting boundaries that are healthy… When we talk about boundary spanners (BS), in this perspective, they have

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some knowledge, some particular expertise within the confines of each of the other two SMEs that they'll be working with. And the purpose of a boundary spanner is to bring those two individuals or teams or groups together to help them in the PSS, shorten the time to get them to a solution, whether that's a project deliverable, whatever that outcome is that has to happen within the PSS. They have specific knowledge and expertise that they are going to bring to bear to bring these two groups together to solve a problem. Maybe it's not going to be a perfect solution; a satisficing solution is what we're looking for. Something that will meet everybody's needs, not take too long….from a project perspective, which is my perspective, on time, on schedule, within budget is what we're looking for.

From what we have started calling model 1, within this 3D PSS, what are some of the contrasts, characteristics of the individual model <the Copeland and O'Connor model> and how it's changing in the second model that perhaps you could speak to.

VC: It seems that the first aspect was all about building a trust factor. And that that would be very important relative to communication because people will only extend themselves as far as they feel safe, secure and can trust. What the individual model related to me was the mechanism that was put into place to build that framework. *Can you stop right there for a minute?*

Part 2:

KL: We're talking about the two models. In the Copeland and O'Connor model, when I looked at it to me it looks like layers of an onion. What that kind of model speaks to me about is that the outer layer of that onion is very superficial; everybody has

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access to it but the deeper you go into the onion it may be more shielded, more guarded. You have less and less access to those layers. What we have found in successful PSS is that everyone needs access to information, communication; it's not just about making sure that the communication mechanics are working – that you've got PCs that can send email. That you have access to people's phone numbers. That all of the technology is working. It's that there is dynamics of communication that has to go on. To my mind, when I started looking at this model and started reviewing it, it said to me that if you really wanted to get to the central point of the model which is Pragmatic and Contingent, that that was much, much deeper than what most people would have access to. To me, it's how much and how close to the surface do each of those rings either provide information, support, a willingness to share, trust. So, in the PSS, there's something called swift trust. And you have to develop that when you're in project teams. But this model that looks to me like layers of an onion didn't really speak to me in a manner that said, you can have access to my core information. There's nothing there about that and in PSS, especially when it's a team that's coming together to work on a project or whatever the problem is that they need to solve to provide a solution, a deliverable, whatever, it may be that with the Copeland and O'Connor model you may not have enough time to develop enough shared context and trust to actually allow people to leverage the core of that model. So the best work, the best knowledge, the best information you can provide doesn't ever make it to the surface because you don't have enough time with project teams to actually execute what needs to be executed in a timely manner.

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The second model, the one that BSIP1 has proposed, I think I like it better because it reminds me of the blades of a server and each blade is some knowledge base or experiential base that you've accrued. And you've got access to that relatively equally. I understand that if you start overlaying the context of technology, there are access issues and security issues. We're not talking about that. We are just talking about each layer is equally available like most information is on a server blade. I think that from my perspective that starts eliminating some of the barriers that I see, some of the boundaries that I see in the Copeland and O'Connor model. And maybe they are not there but that's my perspective looking at that model. I thought this top outer shell is the only thing that's truly available to people that are going into the PSS because that's the piece that surfaced to everything and everyone else. Everything else – you have to penetrate that first layer before you can get down to the parts that really matter; the information that people may hoard…but you see that every one of those rings has a boundary that you have to penetrate. So looking at the second model, I guess I'm looking for, does this do a better job explaining how a BS (because we don't have the other two SMEs placed within this space yet)…does this look to be a more accessible model?

VC: When I looked at this initially, I thought of two things. One was that this was like a kernel; you know, a kernel has a very hard shell on the outside of it. The energy or the rich part of the kernel is deep within its core. And so you have to apply a certain amount of heat…

KL: or pressure…

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VC: …or some kind of external force to hit that kernel to burst it open to bring forth the richness of whatever is there to be offered. That's what hit me when I looked at it the first time. When I looked at it a second time, I thought about surface tension. You know you have a drop and it comes down and hits the water and we remember from our first physics course the crown pops up around it. Again, it seems as if there's going to have to be some kind of stimulus or some kind of energy that's going to have to come from without that will literally impact or effect upon this to be able to share what's within the nucleus.

KL: OK!

VC: These are just the first things I thought of when I looked at this <points to the Copeland and O'Connor model>.

KL: And that's what we're looking for. Because without that base understanding, we can't look at then, how can we take the individual model and ratchet it up to the level of working within the confines of a small team. No, that's great!

VC: I like this model better <points to the reconstructed individual model> because of the fact that it looks like more of an open system. To me, this is a very closed system <points to the Copeland and O'Connor model>. If you look at the way the lines are drawn, it appears that it spirals down and inward instead of being out and upward where it would share with other systems. So to me this is a very confining kind of a model, and restrictive. That <points to the reconstructed individual model> with it being open and again identifying it with other things I have seen, having lived all over, when I first looked at that, it reminded me of tractors that I saw in Colorado that would go across the field. They had an apparatus that would break the surface and stir up of

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the nutrients, the energy of the soil and bring it up, worms and what have you, and other organisms would come and feed on that preparing that for planting, preparing that for growing something up. So I liked that.

Another thing I liked about it was the equal sizes of the circles, because that gives you some sense of respect, that everyone is going to have equal worth, equal trust, equal respect and, hopefully, equal impact, equal input. Like you say, nothing is ever perfect and you don't even shoot for perfection – that's not reproducible anyways. But the idea is there that you have these entities that are going to come in and everybody is going to have a piece of it. Another part of that was I like circles because circles are unending, which hopefully means that they can continue regeneration, they can continue the productivity…

KL: …so the knowledge base would be continuing to aggregate additional knowledge…?

VC: …yes, would continue to grow…. There's a sense of those being connected but they're almost like within one another's field, and again, I'm going back to an energy field, because within your model there the distance is equal and so it's almost as if there's a synergy that holds each within its own axis or area of spin.

KL: Right… and that's interesting because from SME RL's perspective that's what he talks about in his transcript as the bind…and it's not only within an individual person but then it has to be extended to the small team. That's interesting….I like that. One of the things I really like about it being blades whether it's on a tractor and you're preparing the soil or whether it's blades in a server, I like the idea of the accessibility that that, at least in my perspective, brings to this. And from the chemist's perspective, I

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think about knowledge transfer as complete ionic exchange. Two people come together and they do a complete knowledge exchange on some aspect of the business and we see this all the time. A company buys another company – they have to become a new entity. There has to be a lot of knowledge transfer that goes on so that they can then become a new entity. Best of our practices go to you, best of your practices come to us; we come up with an entirely new entity based on that knowledge exchange, that knowledge transfer. The piece that I like about this is, and we've talked about this from the molecular perspective, I like the idea that when we put two more stacks, RAID arrays or whatever you want to think of them as, into this 3D PSS when you put these folks together they are going to be pulling on different blades of each of those servers. The SME may have two or three or more areas that he or she is going to pull on and I see those circles extending almost to the point of being elliptical like you think of in molecular bond theory because you have to have a large concentration of electrons working in this PSS together with the BS and the SMEs working together. Because in molecular theory, you have to have those outer shell satisfied, "satisficed", and you're doing that by providing a solution, by providing input and expertise and knowledge, and so like the bonds, you have those outer shells satisfied. But there's a lot of activity right in those areas where the bonds are being shared. And I think that the <reconstructed> model can speak to that far more easily than the "kernel." I like that, that's a very good visual as to how we describe the individual model, the Copeland and O'Connor model, versus the one we're working on now. That's great, I really like that.

VC: Thank you. The boundaries, that's one of the things that continues to be reflected throughout the body of research. Boundaries are important whether we're

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talking about physics, chemistry, when we get into human sciences because boundaries actually free each element to be itself because it defines it. In looking at the model that's drawn, there is again a sense of space. It's almost like a somewhat uniform space between those three objects, those three circles. But within that space there's also a sense of freedom, there's no gates, no doors to go through. The space is open, both over and underneath, above and below each one of these round discs. Well, with people, holding a business relationship, personal relationship, together, there's almost an invisible – well, you call it the bind – and I think of it as a bond - where there is a connectivity that occurs and the charge keeps the distance, maintains the distance.

KL: That's interesting that you talk about that. Other BSIPs and I talked about that. There has to be enough bind, enough positive attraction, but you also see that if you get too close together then it starts repelling. So, it's almost this bond that you're talking about, it's how you set and maintain healthy boundaries and when you get past that, that's when you start seeing the dysfunction within the system whether it's in a team or a group or here, in the model, between the BS and some SMEs. That's an interesting way to look at it.

VC: Thank you, it's an aspect that's missing many times in a lot of systems that are developed. They don't recognize, respect and plan for that space.

KL: Those environmental factors are so critical. BSIP RL and I had discussions about noise and he had done a really good job talking about interference, inability to understand either because the package, the communication loses some of the package whether it's because you can't hear, you can't understand; he even talked about physical pain. So, there's a number of environmental factors that can negatively impact

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the communication, the relationship, the bond, the “bind.” It’s interesting to hear you echo those pieces, as well.

Currently, the way I’m seeing this set up <the reconstructed individual model>, we talked a lot with my first BSIP about noise and negative aspects and I like the positive aspects of this but, as you know, there’s also negatives. Does the model reflect those negatives as well? The noise aspects? We only have one of these SMEs or BS models in place in the 3D PSS represented here yet. But I’m just wondering – we’ve talked about shared understanding, about trust developing, but how much noise should we or do we even need to represent in this model? I’m just looking from an environmental factors perspective, we’ve really only looked at the positive side. It’s a PSS where you players that are coming together with the expectation that they’re going to be contributing and ultimately they are going to provide the deliverable or the solution or whatever they are coming together to work on in this space.

VC: Axis comes to mind when you’re talking about that, because they each have their own axis plus their own shared axes. And as far as relating negative things that happen, when a system gets out of sync, it literally will shift on its axis. So, how are you going to relate that? There’s many things that throw systems out of sync where it’s not functioning up to par, not functioning at best optimum level. I like the fact that this is 3D because it’s not as restrictive as a flat 2D model. I’m trying to figure out how to relate balance because there’s a delicate balance in every system. Again, I like the fact that it appears to have open-endedness to it to allow input, output, those are things that maintain a healthy system. But the complexity theory is something I’ve been teaching from the past few years and that has to do with all the other things out there as it comes

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from the Gestalt. It's not about one element, it's about the combination of elements which is kind of like your group is, your group is talking about a Gestalt. So, keeping, maintaining a Gestalt that your three people, your SMEs and BS are able to focus on the Gestalt. That's going to be critical because there are going to be other things, outside determinants that are going to be pulling on them, pulling for their attention; you were outlining some of them as pain, or dissonance or resistance. Those are things that are going to be happening. So, you would want to within the model, to demonstrate how you're going to go about this balance because balance will be a key factor in making this model successful.

KL: Well, it's interesting too because some of the things that BSIP RL and I had talked about, he had to go into a PSS. They had thought that they had come up with a solution; they had framed it within the confines of mechanical engineering tools and representations. The team was very comfortable with the symbology; they were all extremely familiar with the taxonomy so it was a very easy way for them to communicate. Unfortunately, the solution didn't work. And they were really not sure why. They knew it wasn't working and that's when they brought a BSIP/SME in to look at the problem. And he looked at taking the situation that they had and he completely reformulated it from a mechanical design perspective and reframed it in an electrical design perspective. So it wasn't just about taxonomy that he had to make sure when he was communicating his presentation as to why the solution that they had developed in the mechanical side of the house had failed but then he had to translate all of the mechanical variables into electrical variables. So, it's not like he came up with something like "you're going to have this many Ohms of resistance for this kind of a

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current," he simply had to take the attributes and translate them into a different perspective and context. And once he did that, he could see very clearly why the solution had failed. That it was not a solution and how you could very clearly see what would work within the confines of the electrical perspective.

The question that I want to pose to you is – and I think I kind of know the answer based on what we've talked about – "do you think that the representation just going from the Copeland and O'Connor model to the reconstructed individual model - because we haven't ramped it up yet to include three folks in there, a BS and two SMEs – does the symbology make this a clearer model for you?" And I'm looking at this again - from the engineering perspective, they are very clear….

VC: …very precise…

KL: …very precise engineering symbology that they use in each of the engineering disciplines. But when we're talking about communication - mechanics, dynamics, team interchanges – we don't have that tool set at our disposal. That was one of the things that was brought up in conversations previously was that if you bring someone on that has very high-level knowledge of tools and symbology and then you put something very simplistic in front of them that they may dismiss it because they operate in such a different realm, higher realm that what you're communicating in that that actually may trip people up. So I am looking at this from an appropriateness perspective – "Is the model appropriate to communicate to multiple audiences?"…what we're trying to display, communicate by a model.

VC: Now this is still one individual?

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KL: Correct. This is one individual. The bind is what is keeping each of the knowledge and experiential bases together. But that will essentially have, in the future, two more of these folks in here because it's not the bind between the knowledge and experiential bases within a particular person but it is within the team. Not to say that there isn't binding, bonding between the various knowledge and experiential bases within a particular SME or BS; there is. It would not be that same person without having the formal education, advanced training, workplace development activities, and experiential activities that you've been involved in and been through. That all binds together, unless you have some very dissimilar industries that you step into, all of that builds on top of the other. And even if you are in some very dissimilar industries, you're still going to see similarities between the knowledge bases that you have.

VC: You bring up good questions, Kate. Whenever you have a basic or a simple model, people have a tendency to project into it. And you have people coming from different paradigms, different areas of knowledge, experience, expertise…

KL: …industry…

VC: industry…and they're going to be projecting, literally, who they are and what they know on the model if it's not clearly defined.

KL: Interesting.

VC: If it's not clearly determined. That's why when you give all these different things to people for you to get into their head to see what they are thinking, the more simplistic, the more identifiable that the symbols are, the more you're going to be popping out what this person's thoughts are, their perception of this. It takes me back to this early childhood example, where you have an elephant and seven blind participants

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and each one would come up and grab a part of the elephant and they each describe something totally different as to their perception of what the elephant is about. And it's kind of like that with models and people; the Johari window, for example, says that every single one of us has four panes that we operate off of. One of the window panes is the unknown; that's the element that you don't know and other people don't know about you. When you get into an open-ended model, and if it is extremely simplistic, that's when you have surprises. And those surprises can pop out in the action and interaction that goes on in the team and can waylay it. It can throw it off-center, it can keep it from bringing in the goal or objective; it keeps them from succeeding which is the very reason that they've come together. So it depends on what outcome you're looking for. And with a model you want to have enough definition within it so that you have a generalized understanding of what that model represents. And if you get too simplistic or too basic, you're going to get too many definitions.

KL: OK, I like that. You talked about the Copeland and O'Connor model as a kernel, talked about is as something that was confining and unless you had some outside pressure acting on it that all of the great stuff that was inside of it wouldn't come out. That's interesting to me because when I think about that from the molecular perspective, we've got a couple of options for bringing molecules together that typically don't want to come together, as you well know. We've got temperature, we can heat stuff up. Sometimes that's enough. Sometimes we can put pressure on the two components and that will be enough. Sometimes it's a combination of the two. And sometimes, there's such a difference that you actually have to use a catalyst. In my head, I see the BS as the catalyst bringing these two SMEs, or small teams or big

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teams together and lowering the energy of activation, because that's what we're talking about here, to bring these two groups, people, teams, whatever, together and actually see some positive things spontaneously happening as a part of what they do. They are supposed to be the catalyst. If they are supposed to be the catalyst, my question to you is: "Should their representation in this 3D PSS look different in this space than the SMEs look like?" Right now, we have thought about this as they are all going to look like the blades of a server. We've got the bind going on between the SMEs and the BS. But if the BS has to be the catalyst, again, this is the chemist in me coming out, catalysts are very, very different than either of the two compounds that are coming together. So, do we need to readjust our thinking about how the BS is represented in the 3D PSS that we're creating?

VC: If you want to have that uniform recognition when people look at the model, and there is going to be a difference in the role that each plays, then you would demonstrate that with a difference in symbols, in my mind.

KL: OK! So, let's just play. Let's just look at this <the restructured individual model>, and if we have a couple of these – let's assume these are the SMEs – how would we better represent catalysts? When you think about BIO 101, which is typically where you introduce catalysts, they typically have a couple of puzzle pieces coming in, zooming in, and there is a third puzzle piece down below that the two puzzle pieces fit in to perfectly and when they come together with the catalyst piece, they also interlock themselves and then when they leave the catalyst they either represent the transformation by a different color combination or something. Is that something that

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we're going to need to represent in this model? Would it be wise for us to circle back around and think about this?

VC: What I saw when you were saying that was an allergen. You know when you see the commercial of the allergen?

KL: Right.

VC: And it is a round sphere with many, many points all the way around it? And wherever that point touches, down the nasal cavity, down the throat, whatever, wherever that point touches, it stimulates. That's why the nose itches, the throat itches, the body releases secretions, and that begins to stimulate different kinds of circulation. And so, if you're going to have the knowledge disseminator, you have your two SMEs and your BS, that BS would need to be represented or demonstrated by an object or symbol that would be stimulating. Because every time that entity comes into the configuration and they are working within the system, something should happen! Hopefully, positive; always hopefully positive! But that's their role! That's actually their definition, that's what they do, that's who they are. So, they come into it and they stimulate it. And I guess you really wouldn't want to use an allergen because people don't normally see that as a positive! <chuckles> But I'm trying to demonstrate the object that I see, the design of the thing. It doesn't have to be that, it just needs to be something that represents that kind of dynamics.

KL: OK, we'll have to circle back around and model 2 is going to have to include some different symbology so that we understand or at least can represent something like that within the context of the model. That's the piece that I have felt, as much as I have liked this one because it's more open, it allows me to work with the various

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knowledge bases that I'm representing in here as circles and extend them to look elliptically to look like orbitals that are integrating. But the piece that has bothered me is that putting three of these together in the PSS doesn't clearly represent what we're trying to in this. We've got BS with very different attributes that they bring to the space that the other SMEs do not.

VC: And these also seem like they are solid. When you look at them, even though we're talking about three tablets, they're like tablets; the three tablets are suspended the same distance and they hopefully they maintain that homeostasis…

KL:B certainly his drillings and completions experience is a very large part of him as is his electrical engineering background. And then he's got less from, say, a curriculum design or competency development perspective because that's not what he's done most of his career. So, the idea of being able to grow some of these shapes to represent more or less knowledge and experience is going to be crucial, I think, to the model. Just to help people understand that we don't expect that everyone is going to be coming in with the same level and breadth and depth of experience. So, I think that, perhaps, tha t may be misleading. So, in the future, I think we'll have some differences as far as sizes of shapes and perhaps depth, just to better represent what we're trying to explain here.

VC: That makes sense.

KL: It's not just about the taxonomy but it also is about the symbology. We're trying very hard to make it as neutral as possible from an industry perspective and a symbology perspective but a lot of this you still have to talk about because it's just not going to be representative to multiple people. The simplicity has to be such that you can

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project from your industry, from your perspective, from your context, your shared understanding – what does this model say to me? With the Copeland and O'Connor model, that's the question I've been asking every single person. You just need to look at it and tell me what you see there. So that's been very helpful for us because then we can take a look at this model <the restructured individual model> and say what do we need to change?

So, from a context perspective, when we make these changes to the model, would you say that it is still going to be something that can be applied to multiple contexts after we change it? Will it be simplistic enough? We talk about the Copeland and O'Connor model being Non-Deterministic. Meaning we want to be sure it is as applicable to as many contexts as possible. Are we going to be there when we make these changes?

VC: I think that you can. I think that it's possible. When I was looking at this earlier and I was looking at the different areas in industry that it could be used in and thinking about the different kind of dynamics that were involved in each one, you do need that kind of, not bland, but identifiable simplicity. It can't include too many bells and whistles because then it becomes specialized. So, to have a generalist type approach is what I'm hearing you say you want it to have, that generalist smack to it so it fits into many different areas as opposed to one.

KL: Right!

VC: Like a specialist.

KL: Let's pursue one other topical area that I feel we were maybe a little brief on. With respect to the model as far as mechanics of communication and dynamics of

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communication, do you think that that is something that needs to be represented in the model? By two different models? Does it even have to be a part of the model?

VC: I think it does. And the reason I'm saying that is because we're getting into different age cohorts, people are going to be coming in with different areas of reference, our society itself is changing and so people are going to need mapping, they're going to need processes, they need models that they can look at so that they can understand how to get from here to there. You can have the most perfectly formulated plan, model, to achieve an objective and if you write out the soft stuff, the people side of it, the communication, the relationships….

KL: All the change management processes that have to go into place…

VC: …that's the very thing that will drive you into a shipwreck; your boat will go off course. That's actually a form of crisis management. Because if you figure in ahead of time for the very real context of humanness that's going to be involved in performing business models, you have a greater chance to figure in addressing crisis management, you know, taking care of it before it becomes an issue.

KL: Right.

VC: I think that if people have something to look at, they can at least start thinking about the fact that they need to see this happening in the system that they're putting together and if that's not happening, that would be an area of concern. So, is there contact, and is there a genuine sharing, and are people just getting together and rehashing the same thing or are they moving forward on the problem solving? Are they actually making some kind of resolution and how are they able to test and track for that resolution? Those are things that come up.

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KL: That's one of the things that my first BSIP and I were very clear about – we really wanted to have this called the 3D PSS because the dimension that a SME brings and the dimension that another SME and a BS brings to the PSS puts this up into a sort of a 3-dimensional, 3rd dimension of problem solving. You've got everything that you bring into that – I think of that as breadth and depth – that's why I think prior to that until you bring the 3rd dimensions which is additional layers you don't enter the 3rd dimension. But we call it PSS, we don't call it problem failure space (PFS). So we're presuming that this is going to be a positive, rich, energetic, solution-oriented team; not to say that there aren't a lot of spaces out there that are PFS because of all these issues that we're talking about. And so that's why we're still kicking around the idea of how do we, or do we, try to represent PSS vs. PFS? Is that even important? So, that's why I'm posing the question to you, do we have to represent the PFS? Because that, to me would be where the healthy boundaries are gone; there are boundaries but they are not healthy. They are the sorts of things that we talk about in industry as siloed mentality, lack of trust, lack of sharing… there's loads of this in the literature…. Information hoarding, power strategies that do not support the group, all of these things come to mind.

VC: Right.

KL: So, that's why I wanted to circle back around and say, what about this?

VC: To me, it would be a better representation to see what it looks like when things are going as they need to go and how it looks when it's a train wreck. And the reason I'm saying that is because when you have these groups that come together, you have all these different stages of development. And for some of these folks, this may be their first rodeo.

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KL: Right.

VC: So they don't even know what it looks like when it doesn't work. We are so focused at looking at, figuring out what it looks like when something works, and yet the reality of it is that the most learning comes about through failures, right?

KL: Right.

VC: And for every inch we move forward in science or any of the fields, there's been miles of failure. So having people come together to work in a group, again I'm thinking from a crisis management mode, they need to know what hurricane warnings look like so that they can get up and do something about it. So that they can address it before they get to the point where it's all over with guys and we didn't make it. So, if they had the model that said "warning signs," these are warning signs that things are not where they need to be, that would allow people an opportunity to get up and adjust. You know, you can adjust for drift; you can adjust for all kinds of things. But they would feel more on top of the situation as it unfolds.

KL: It's interesting to hear you talk about that because that was one of the things that, as other BSIPs and I have been chatting extensively through this whole process, that's one of the modeling tools that engineers have access to – they can actually model and assess multiple attributes at the same time. We've talked about this, you and I. If you have fluid running through a pipeline, you know the rate of flow, you know whether it's at standard pressure or if it is under pressure, if it's pressurized. You know the heat, you know any number of these attributes and control systems engineering has sensors that can give you live data feeds. In trying to set something like this up from a modeling perspective, whether you're talking about it from the mechanics perspective of

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communication vs. the dynamics of communication…mechanics – you actually might be able to assess some of these attributes. If a team's working well, you could maybe look at how many emails are being exchanged, how many meetings are taking place, the sorts of IM messages that go back and forth because a functional team is very communicative. Whether there are language barriers or whatever, that's one of the things that one of the BSIPs points out is, if you want to work together, if you're going to make this work, you'll find something in common with these people and you will make it work.

Flip side of that. The dynamics of communication – and that's one of the things that I find interesting – looking at the dynamics between people when they're communicating and looking at it from his perspective. He talks about resistance; well, we talk about unwillingness to communicate, lack of willingness to communicate – that's resistance. He talks about current and flow; well, you can see if things are really heating up in a team because there are a lot of things you can assess on the mechanics side. But if it's not working, the dynamics piece then becomes very difficult to assess. It's not like we have physical attributes that we can measure to ask "What's the problem?" <Example:> Kate and BSIP2 are two SMEs and we expected that they were going to be leads in this PSS and they haven't talked to each other the whole week. Not one email, not one IM; what's the problem? And BSIP2 says, "nothing's the problem." And Kate says, "nothing, there is no problem. We have no problem." And I would say, REALLY?!? So, that's the piece I'm a little concerned about. From the mechanics side of the house, we can suggest some of the things you look for from a positive perspective in mechanics and the same if things are going south. But the dynamics, those are the

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attributes that I'm not sure how we could represent either from the positive or the negative side because they are…I don't want to say that they are immeasurable because you can always find a way to measure something, even if it's with sentiment surveys. But you and I both know that people actually have to be honest and if there's no trust, people aren't going to be honest. You can go through a survey and give them whatever information you want. This is where the other BSIPs and I stopped and said if we would have to represent one model for mechanics and dynamics, I think we would struggle very hard for the dynamics part and if we would have to set up a model for mechanics and dynamics as far as measuring or assessing, I don't know. Because if we're going to have to do the PSS and the PFS, I hear what you are saying…when things are going well, it should look like this and when things are going badly, it looks like this. From a modeling perspective though, you have to have attributes that you can model either with something generic – shapes, whatever – or we have to give them a certain list of attributes and it wouldn't be in a model-type format…I'm just not sure how you would represent this in a model.

VC: What comes to mind on that, one of the biggest problems in any kind of project that's one with more than one person is passive-aggressiveness. And you know, people like you said, Kate and BSIP2 are both smiling, everything is great…but what came into my mindscape when we were talking about that was the actual symbol for an email, the symbol for a cell phone, the simple symbols of communication. And you can demonstrate there's a stoppage here or a blockage there. Let's think of all the different dynamics, all the different measures with which people communicate, because one of the biggest red flags on a project, like a clogged up circulatory system, is the cessation

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of real communication. And in real communication, we are talking about the project, we are discussing the project, and we are building towards something <gestures like steps leading upwards towards a peak>. So, let's say you had a pyramid with stairs going up and on the stairs, it's really not a stagnant pyramid, it's almost like an escalator. Because you have communication – you have emails, you have cell phones, you have chats, webinars – you have all of that and everything is showing that this is like liquid, this is not a solid, it has to be a liquid, it's fluid…it's moving. <hands moving up and down>

When that stagnates or stops, the project, the project team is in trouble. And so, how would you demonstrate that in a model? Well, you'd have to use Universal Recognizable symbols, all of which have to do with communication. One would actually be face-to-face, another would be email. Many of us today are computer literate and so we recognize those universal signs, symbols that represent communication. So, that would be one way to demonstrate in the model. Avoidance is another way…you talk about resistance.

KL: Yes, those are things that from an attribute perspective, you can measure the Ohms of resistance in an electrical circuit.

VC: You can measure it in a people circuit, too. Resistance comes from not returning emails, not returning calls, missing meetings, all of those things are measurable. So that begins to let you know, this whole human factor is off-kilter here. These two people aren't talking to each other here, or these three people aren't talking to each other and the interesting thing about three people in your team – three people is always a difficult combination because you can always have two gang up on one. That's

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one of the things they look at - anytime you are looking at a triad. And that's another factor in itself although the reality is with the lack of funds, the lack of resources – you're good to be getting three people to work on a project, right?!?

KL: Right…!

VC: Correct me if I'm wrong!

KL: No, you're right! That's why we're trying to take it down to the smallest group that could be considered a team – and I'm not saying there can't be a two-man team – but a BS needs to have at least two groups with whom they're working and that they must come together. That's sort of the definition of what a BS does. Certainly we could bring three or four or 10 or 25 groups or SMEs or whatever together in the mix but from a modeling perspective, I think the simplest is two SMEs and a BS. And that's the only reason we've selected that. If we think that the triad would bring other issues to people taking the model and personalizing it for their particular circumstances and context, then maybe we need to think about switching it up to three SMEs. That's certainly worth a thought.

VC: Because some of my teaching, I look at everything from that SWOT idealogy; you look at Strengths, Weaknesses, Opportunities and Threats. But when you're measuring anything with people - I kind of look at that in the same way. Look at each person as a system, look at combinations of persons from: what are the strengths of the group, the weaknesses of the group, the threats to the group, and the opportunities with the group. Threats - always - first - foremost - <to any group> is communication. And so with bringing that to the board from the model so they understand that it is that important that they must communicate and it has to be relative

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to the project and people need to get answers to questions – those are all things that need to be a part of it. When you put together any teams, if you actually have people trained up where they know "you and I are going to meet this week, I've got to present you with three questions that I foresee that are going to sabotage the process we're in and you're going to do the same for me and we're going to talk about it." We may not be able to find a resolution immediately but the very first step is awareness. You have to be aware because I may be looking at what we're doing and I may say "I see no problem." But that's because of my particular knowledge base.

KL: Your context, your experience….

VC: …my context. But you, like your good friend, the engineer, taking it from the mechanical to the electrical, he brought in another set of eyes, another paradigm. And he immediately saw things very differently. So, the fact that you have three people coming in, hopefully, even though they have commonalities and shared bodies of knowledge; hopefully, they will have different knowledge bases because that gives you a clearer picture of what they're looking at. That's another thing is to have the model demonstrate that having differences is a strength instead of a weakness and a value. I haven't seen that in too many organizational models; to be honest I'm thinking in my head that out of all the organizational models I've looked at, when have I ever seen differences related as a positive, or as a strength? And you, with your background, how many times have you seen that? Maybe you've seen that a lot of time…?

KL: Some, but I certainly wouldn't say a lot, no. I think that it's more lip speak than actually being part of the culture. After all this time…

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VC: And I can tell you, from having taught online classes since 2002, 2003 - so we're talking 10, 11 years - and I get a class - and they're all grown up and they're all working - and I'm doing this on a master's level so a lot of them are professionals - and when they come in and they tackle problems together that discussion piece of the course offering, they shock each other. They'll say, well, I'm coming from this background so I'm seeing this and the next student says "Well, I didn't see that at all but I do now." And so that's where that communication factor and sharing knowledge bases is very important. Because it better defines the problem, and when you really can see what you're addressing, you're usually better at coming up with resolution solutions.

KL: Umm Hmm. Interesting.

VC: Now, I can respect the challenge of relating that onto a model that's going to be printed. I can see the model in a holograph. I can see that…

KL: Yeah, in 3D space… I think that's one of the things that when Dr. O'Connor and I were talking about this model <the Copeland and O'Connor model>, in the book, he's got some additional follow-on diagrams that were part of this one. They had not expected to have to deconstruct their model as far as they did to show pathways but the publisher wouldn't accept it. So, it's interesting that you should go there because that's one of the things that becomes problematic. Other BSIPs and I talked about that; and we've talked about that even in this discussion - the rendering of the model. One of the BSIPs is very used to working in a 3d environment with the engineering tools that they have and today you can place an avatar in many of the engineering design tools and actually allow the avatar to walk through the plant and you can have it assess some of the dashboards like a person would if they were at the plant site. You can see what you

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are getting for direct feed attributes for the fluid in a pipeline, in the exchanger, in the towers, whatever. You can't do that here….we're not working in 3D space to which everyone is going to have access. I think that for the Copeland and O'Connor model, the publisher wouldn't give them an opportunity to include the diagrams that they had put together on a CD or a DVD to accompany the book. They apparently weren't going to spend that kind of money on it. So, I think that's one of the other things is that we've got to put the model together so that – lowest common denominator, it's on paper. If we're going to have to put it together so that it can be rendered in 2D for the dissertation, what sorts of limitations does that impose? As you can see, I've currently got the mock-up in Visio (2010) which is 2D because I'm trying to plan for all of the possible constraints…the most stringent constraints is going to be on a screen somewhere, it's not going to be 3D. So, I've been trying to incorporate that but it's very clearly going to be an issue and a problem.

VC: That is a challenge.

KL: In my head, I can see this <the model> within the confines of a cube, a sphere, whatever you want the PSS to be…

VC: I almost see it as a cloud. With all our technologies now in the cloud, problem-solving is not necessarily on the ground.

KL: No.

VC: …because people are doing so much of that virtually. So, you almost see that coming through in a cloud. I can certainly respect the human factor being very, very difficult to relate in model form. I will tell you that we had models that we used that were trying to relay the very things we are talking about, the different ways people relate,

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communicate, and along with communication you looked at behavioral aspects, too. And you cannot count out the human factor because, to me, that's one of the reasons we're concerned as a country because I don't want to be negative about each age cohort and what it brings to the table but our people are evolving very differently now. Their social systems are different. But work still demands a certain kind of a product.

KL: Typically, it's very contractually defined.

VC: Very!

KL: And you're given so much of a budget to do it, and so much time to do it and you'd better develop a schedule that allows you to complete it within those constraints. Because if you don't, very typically, the contract has sanctions included in it.

VC: Yes!

KL: If you do not complete in "X" amount of time, we will not pay you as much money or you will pay us a fine or whatever; it could be any number of things.

VC: That brings me back to what you were talking about. Another issue that comes from the people side of this… I teach a course "Managerial Issues" so on top of everything else, our teams are looking very different now. You can have 3 people in this triad that are coming together from 3 different cultures…

KL: Absolutely!

VC: …and that's very typical especially in oil & gas and a lot of different industry areas. So, you add that and that's a very powerful influential factor in whether or not that group creates the bind and whether or not they're able to perform together. And we haven't gotten to the point yet where we have 'global manners'. Each culture has its own acceptable or not acceptable morays and so now you have 3 people that are

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coming together and you have managerial issues and diversity that are also going to have an impact on whether or not this manifests, whether it's successful or not. So, that's another element and you do need to relate that somehow in a model and that would be, I don't know; you'd have to find a Universal sign for respect and for trust so that when you have people coming from these different social structures, and different cultures, etc. that they know that "you and I may not look alike, we may not be the same gender and practice things not alike, but on this project, we both have to have 100% buy in and commitment to positive conclusion together."

KL: That's interesting from a symbology perspective; looking for common symbols for trust...

VC: So that everybody gets it, no matter where they come from. I have students, right now, today from Saudi Arabia, Dubai, I have students in Dallas, in Iowa, I have people coming from all around the globe. So when I'm talking with them, I'm very much aware of this factor we're talking about and I have to figure this out when I'm setting up classes and how they are going to work together.

KL: Those dynamics are just as huge for the work that you're currently doing as it is if not more so in industry.

VC: Oh, yes!

KL: Because what you give them is what they are going to take out into industry.

VC: And I have students that are in the oil & gas field. Even though I'm teaching in the Public Service Arena at the moment, I've had students that work in Corporate and they are very concerned about what is happening within Leadership and Management. This is the killer – they actually are in business but they are coming to the Humanities

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side of the house to learn people skills, soft skills because they have already figured out that it's not having that that's causing their companies to fail, their corporations to fail. They've got all of the business dynamics – they cannot have two, three people sit down, come together on a project and successfully bring it to resolution. And the students that are getting hired, my graduates, are telling me that they are very surprised – they are applying for corporate positions in corporate offices and the HR people are pulling up their resume and asking them tell me more about this certificate you picked up, Management and Diversity, Leadership, Strategic Planning… because I need people in this corporation that understand how to talk to people, that understand how to communicate, that understand how to relate to people. So, we're finding something kind of shocking happening in my limited experience; we've got people that have always been business people but they're coming to this program and taking classes with me because they've got to have people science, people skills, soft skills. And it's because people can't get projects to manifest anymore because of the things we've been talking about: resistance, passive-aggressive. You know, I came in tonight and I pulled up an article that said 30 million people in the US have personality disorders – how do you deal with that in the workforce? In spite of all of the challenges and complications, how do you put together a model that shows a person no matter who they are, where they're from, what society, gender, age, whatever – this is our pathway, this is our guideline. If we follow this, we have a much higher percentage to successfully complete. That's what they need. And they need mapping; things that later cohorts don't even think about, the cohorts that are coming in to management and leadership positions, they are going to have the college degree, they are going to have the college-generated knowledge and

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skills, they're going to have had internships with real life experiences in the field. But what they are going to be missing is how to deal with relationships and communication. And what we've learned, the more we get into technology enabled communication, there's more and more of a loss in ability to relate to people.

KL: We are already hearing about the lack of skills because it's much easier for people to text or email or whatever.

VC: The change in family – people no longer sit around the supper table and communicate with each other, people eat in shifts. So, they don't learn how to relate at home together and then they get into school and our school systems have taken out recess where they learned social skills. It's taken out any kind of an opportunity to relate to one another in any way that's not about getting a certain amount of crunchable testable knowledge in them. They don't get the social skills in the elementary, junior high, high school; then they get up into college and they're working. So they have no engaging community there. So, where do they get that now in the continuum – where do they get to learn how to get along together, communicate, and successfully achieve together? Where does that come from? They are going to need models that tell them because they are still pretty good about putting together things from a model. And you know what this makes me think of? This makes me think that models in future are going to look like our computer games today. They are going to be like a computer game because we are already going to a paperless society.

KL: Certainly that's what some of the plant modeling software looks like. It looks very much like game software!

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VC: I think business software is going to go in that direction, too. I think it's going to have to. What they use in the Army, they pull kids into the Army by sending out discs to the house for years where kids would play an Army game and it pumps them up and gets them pulled right into that mode where they want to go into the Army. Well, then they have other modes that do that. So, I think that in models like this, they are going to have to go to discs; they are going to have to go to computer discs, DVDs, that kind of thing. To where people, the thing that you're talking about being hard to relate right now, because it is on a flat 2D piece of paper – that's very hard to relate. And I don't mean to derail us because that's probably where you're going to stay, but in my mind's eye I see this being better related on a DVD…

KL: Right, so you can render it, the dimensions that people can explore…

VC: …and I've noticed here in the last 10 years of my career in directing and managing programs, people would send me the little ones, the little discs as a communicator. And the reason people were telling me they were sending the small discs was they know they cannot have but a minute of your time, and with this whole thing about symbols, they are telling you when you get something this big <uses her thumb and index finger to create a circle>, I'm not going to take 30 minutes of your time, I just need five. Give me 2 – 5 minutes of your time. And so, when it was a disc that size, I'd just pop it in, play it and they'd get their message across. So, I think for those of us, who are working to relate business models, we may find that we're going in that direction, as well.

KL: Well, maybe we have a link to the space. There are permanent URLs out there. Maybe with something like this you set up a permanent URL and allow people to

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render 3D images on their desktop, you just give them a URL that allows them to go out there and see it in the form that you want them to see it. That may be an option because you're still doing something hard-copy because you have to give them something but perhaps we think about a permalink.

VC: Just a thought….

End of Interview Transcript for SME VC

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APPENDIX E

INTERVIEW WITH BOUNDARY SPANNER-IN-PRACTICE (BSIP) TG

JANUARY 20, 2013

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Appendix E

Interview with Boundary Spanner-in-Practice (BSIP) TG

January 20, 2013

KL: I have been assessing how the Copeland and O'Connor Non-Deterministic Model of Engineering Design Activity could change if you were not looking at the Problem Solving Space (PSS) from the perspective of a single individual working in this space which is represented in the current model but rather from the perspective of a group of individuals. So, specifically we're looking at it from the space occupied by a boundary spanner (BS) and two Subject Matter Experts (SMEs). That's the smallest group that we can determine would work within the confines of a boundary spanner's role because they are bringing two groups together with the BS having expertise in each of the groups represented. They are working in the PSS to help the two groups come together, be more efficient and effective in this space, come up with a solution, deliverables, whatever is required.

I have been working with BSIPs to begin the process of model revision and I provided you with a transcript of our videotaped conversation so you would have an understanding of what we had talked about up to this point in time.

Today, I'd like to gain your perspective on the model we're proposing. You have been selected to review the work we have completed because I believe that you have also performed work typical of boundary spanners either previously in your career or are an active boundary spanner in your present role which is why I am asking the Delphi participants to come in, using this conversation as an iterative approach to ask, "Are we

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on the right track? What should we change? What should we reconsider?" based on what we have done so far.

So, we will be talking about some questions based on previous conversations I have had with other BSIPs. There is no right or wrong answer; what I'm looking for is your perspective on the work we are doing so that you can further inform the model that we are working to develop. This may not be the only time we talk together; we may have one or more iterative conversations.

We can take stretch breaks or bio breaks as necessary. Typically, our sessions range from 60-90 minutes. We will try to take a break during our time together just to allow us to get up and stretch. There is water and a comfy chair to make the session and the interview environment comfortable for you.

One of the things I found interesting from my perspective in talking about this with other BSIPs is that really felt that what was important when we start changing the model from the current iteration of it which was developed for a single individual was that the SMEs have to be on the same plane. To me, though, a "plane" is one two-dimensional mass, very flat; and instead, I'm trying to have people conceptualize the model as more of a 3-dimensional PSS. Another BSIP and I have talked about a SME or group brings a particular set of knowledge bases, experiences, and expertise to the PSS; a second SME or group brings a dissimilar knowledge bases and experiences – however, equally valuable. The BS is there to try to bring each of these people, groups, teams, together so they become a working entity quicker, more efficiently.

When you look at the Non-Deterministic Model vs. the 3-dimensions represented in the PSS, what are your thoughts and perspectives taking the model from the

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individual to the multiple - BS and 2 SMEs. What's your perspective on the plane, everybody needs to be on the same plane? I think of that from the binding, "the bind" perspective. Everybody has to be there contributing, wanting to work together but I'm not sure about them all needing to be on the same plane.

TG: There needs to be a communications level that everyone needs to understand. The term boundary spanner I equate to being a facilitator. Someone who is either able to translate between the two groups or bring together two groups in a cohesive manner that can take the information or the project data provided and work with it in a usable way in the problem space to achieve whatever the goal is. As far as cohesiveness goes, there does need to be a similar level of communication. There may be personality differences, there might be cultural differences between each group that need to be overcome or at least melded together so that it becomes a team, per se, working on the same problem. Each member of the team has their own point of view, their own perspective, their own background, their own experiences whether it is in the actual area being addressed or not but taking advantage of all those variables and putting them together in a package that would work well to achieve the deliverable, the goal of the project – the problem is to solve the problem.

KL: Yes, that's the point, that's why they are coming together. So, you're saying they don't have to be on the same plane but they have to be coming together with a positive attitude and expecting that it is going to be PSS not problem failure space.

TG: Yes, that's correct. In my point of view, it also has to be headed in a positive direction where you don't have someone or a group that's decided that they want to take the glory, that they want to take credit or take over….

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KL: All the power dynamics that can come into play…

TG: The control factor is what I'm looking for as far as an explanation so that again, the idea is to reach the solution to the problem and create a deliverable.

KL: Tell me, when you looked at the model, what were you initial expectations or "impressions" might be a better word. What was your impression the Non-Deterministic Model that Copeland and O'Connor put forward?

TG: Being Non-Deterministic, it's not designed or set to a specific target group.

KL: Right.

TG: So, it needs to be fluid and flexible.

KL: Does it look fluid and flexible to you?

TG: What I see is kind of an eccentric target, where you have the ideal, the Pragmatic and Contingent in the center and the outer rings are different levels of variables.

KL: Interesting!

TG: Again, being eccentric, you can get really off-balance, I think.

KL: Ahhh…that's an interesting impression of how the model speaks to you. That's one of the things I am working very hard is to gain impressions of this model (the Non-Deterministic model) and then taking a look at what we are putting forward, Model 1 of the 3D PSS. The three disks that you're seeing there comprise a single person or group. They are going to be bringing knowledge and experiential bases to the PSS. I'll have to add another stack like that to represent another SME and then we'll have to bring another stack together to represent the BS.

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You've got a myriad of experiences and positions that you've held in the past and the piece that I have valued that you bring in to the Delphi group is because you've got this really broad range of life experiences, job experiences, industry experiences. You've probably got the broadest sets of symbology that you've worked with across your career. The next piece that I want to take some time and talk about is the representation of the 2 SMEs and the BS in the PSS. Now, I've represented the knowledge and experiential bases for this one entity, whether it's a SME or BS doesn't matter yet, but they are the same size and I'm not sure that this really works because you may have significant expertise as a drillings and completions engineer, you may have serious experience with electrical engineering, you may have a lot less experience in this area or that area and the discs right now are sized the same.

TG: <Shakes head and make sound as in agreement.>

KL: So, to my mind that speaks to me that every knowledge base or experiential base that you're bringing to the game, to the project, to the PSS, would be the same. So, my question is, is that a misrepresentation? Should I resize some of the discs to help people represent and understand that we're representing the breadth and the depth of each of the knowledge bases and experiential bases that we bring to the PSS within this entity whether it's a SME or a BS would it be better to represent them <the discs> differently as far as sizing?

TG: In my particular case, yes.

KL: OK.

TG: I'm what I consider to be a Generalist. My experience at this point is as systems administrator working with computer systems. There are areas that I'm very

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knowledgeable in and others that I'm not so knowledgeable. An example would be program languages; UNIX and LINUX are a weakness in my case versus working with Windows and other programs which is my forte. If you would assign a disc to LINUX, UNIX and one to Windows, there would be a great discrepancy in size.

KL: Ok, so that might be a better way to represent this. We've talked about "the bind", and the bind is really more of a representation between the BS and the two SMEs but there also has to be the bind that comes from your experiences with field work, your experiential bases do tie your knowledge bases together. So I see the bind representing not only that within an entity, SME or BS, but then moreover it's got to be the bind or "what bonds these people together." The other piece that I like about giving different sizing to the knowledge bases and experiential bases is from my perspective as a chemist, I think about it as ionic exchange and molecular covalent bonds. When you're in the middle of a knowledge transfer, let's say a company has been bought outright by another company – those people have to get in there and a lot of knowledge transfer has to go on. And the expectation in a positive healthy new company-type environment is that in this knowledge transfer you will take the best from the acquired company and the best from the acquiring company and will be building a new entity. The new entity will be bigger and better than either of the two pieces that were previously alone. And so that's why I'm looking at this and thinking, if we have different experiential-sized knowledge base discs, different-sized experiential discs that people are bringing together, when you're bringing people into the 3D PSS, I can see those experiential bases that you're going to be bringing together like in a molecular model where you have covalent bonding, really, in this space it's going to look more like covalent bond-

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type representation where you're going to have certain of the knowledge bases or experiential bases pulling together into a space kind of like a shared bond. There's going to be a lot of activity there like there is in a covalent bond; that molecular type of bond has a lot of intense electron activity because those atoms that are coming together have to share those electrons in those outer shells because otherwise those shells are not satisfied and you'd lose your covalent bond. And I think if we re-represent it so that you've got different sized discs between the BS and the two SMEs you could bring those elliptical, instead of round, discs together and make it look like more of a covalent bond and you can see all the different pieces that the SMEs and the boundary spanner are drawing on to make the PSS work in a positive manner to develop your solution, to develop your deliverable, whatever the entity is that you're creating.

TG: Ideally, you want to represent them even as puzzle pieces that can fit together. One SME has strengths in one area where the other has weaknesses but the second one has strengths in areas where the first one does not. By interlocking or taking advantage of….that's not a good word for it…

KL: …leveraging…

TG: …yes, leveraging the two together, then they become very strong relationship and as in your covalent bond example, sharing an electron works, it pulls them together….

KL: Right.

TG: …and they form a team just like an H2O molecule.

KL: Right! The piece that we're trying to explore with the BS is "why do we need the BS?" In the case of the water molecule, that's an interesting representation because

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the “O” could represent the BS and the two “H”s could be SMEs. In some instances, the two SMEs, groups, teams, could have a very hard time coming together due to environmental factors, different cultures, no shared context - maybe antagonism if it’s been a recent merger, acquisition, whatever. The role of the BS is that they have knowledge that pertains to both groups and they can bring those two groups together to work more efficiently more effectively to get the more positive interactions that are required to actually move it forward into PSS, not problem failure but PSS!

TG: Right!

KL: I’ve talked about the idea of them being catalysts because catalysts lower the activation energy, that’s what they do. Some things are really hard to bring together with a resultant ionic exchange or covalent bond. You either have to change the temperature or the pressure or both and sometimes that’s not even enough. So that’s when you need a catalyst.

TG: I totally agree with you there. Again, a BS I kind of equate to the facilitator trying to manage both SMEs, breaking a communication barrier if there is one, soothing any antagonism if there is any; that’s the purpose I see for them. Like the water molecule, to make a water molecule, you have two hydrogens and one oxygen atom. If you put them out in a space, they are still going to stay as hydrogen and oxygen until some energy is put into it such as a spark and then it causes unification and sharing of that ion. It takes outside energy and outside influence in many cases to make a project go together.

KL: That outside energy whether it’s a catalyst or a spark or whatever, it’s important to think about because in a lot of instances, groups, teams, or whatever,

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simply think of themselves as “the us” and do we need these other people? Why do we need these other people? And without a BS, perhaps pointing out the strengths, the opportunities…

TG: the contributing differences….

KL: the translation many times is absolutely crucial because otherwise there can be a lot of miscommunication. The symbology that one group and the other group are using may not transfer and translate appropriately.

We talked a bit about communication and I think that’s the really interesting piece for me with the model. Mechanics and dynamics in this are going to be really important. Most of the models we are trying to put together here are about communication. Mechanics, when I think about it from the IT perspective, are the various modalities – transfer packets, are we dropping packets, are they getting there in one piece? My first BSIP and I had discussions about noise – what happens when there is interference? What happens if you lose parts of a package? Then you don’t get the whole enchilada, you don’t get it from start to end so you may be communicating forward with a biased piece of information which is a problem. I’m wondering if we need to represent the mechanics which is either the face-to-face conversation or email or IM or whatever – it’s how you get the information, whether it is file transfers or whatever and do we have to represent that as compared to the dynamics. Because what we were talking about was the catalyst – that’s dynamics – that’s interchange between people, whether it’s getting an environment where people trust each other, whether they get to the point of some shared context that they didn’t realize they had that the BS communicates to them. Those are the sorts of things that from a cultural or language perspective – if you have

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people that only speak Arabic and another group that only speaks English and they are put onto the same team and told “here’s the problem, here’s the deliverables we need, good luck, go!” There’s all of these people interactions – these pieces are on the dynamics side. Not to say that there aren’t issues on the mechanics piece or side as well. Knowledge hoarding – maybe that’s strong, maybe just not sharing information willingly – or that kind of thing is more on the dynamics side, the negative side of it. I’m not sure if the model needs to be representing both the mechanics and dynamics as part of the model; does there need to be two models? Or does that even need to be included?

TG: Well, I do believe it needs to be included. And I do believe it can be a single model that includes both dynamics and mechanics because both are factors in achieving the goals.

KL: So, it just is attributes of say, a physical entity - like we’ve talked about fluid in pipelines like flow and pressure and temperature – those are just all attributes so we could just represent that as attributes.

TG: Attributes of the SME.

KL: Variables or whatever we decide to call it.

TG: That’s again where the BS needs to take the lead on that because they are an interested third party but they are able to look at both the other entities from an outside view and try to discern what the differences are and work out a way to make things work. Now whether your variables such as the dynamics and mechanics of different languages, different cultures, the mechanics of how the communication is done

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whether it's email, IM or WebEx or whatever, if there's a language problem, OK, we need an interpreter. That's where WebEx would be very good.

KL: Right.

TG: For IM, when one can't read the other one's language, that's useless. So again, the BS is the one coordinating how information is transferred. Second, the information needs to be trustworthy. The communications need to be trustworthy. As you indicated, if you had a bad packet, that information is useless so it either needs to be re-transmitted or transmitted in a different form.

KL: So that it gets there in a way that it isn't damaged.

TG: Also, the BS, from an outside viewpoint is able to see if there is information hoarding, or should be able to see if there is information hoarding, if they are observant, and/or even manipulation of the information to give one group advantage over the other for whatever reason which is counterproductive to a team.

KL: Right.

TG: We talked about a team being most productive.

KL: We've talked about this, one of the BSIPs and I, with respect to the environmental factors and the dynamics and mechanics of communication and he talks about this as "the bind." And we've talked about this previously with other SMEs as a bond and the BSIP represented it really clearly. If you really want to work together as a team and you're coming in to PSS, not problem-failure space, there is always some way, some 'thing' that you can come up with that you're going to find in common with other people. Typically, it's going to be a number of other things. So, I'm wondering with communication mechanics and dynamics if that's something that we should consider

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representing within this “bind” or bond arrow and that maybe we somehow represent those environmental and communication factors in that piece – just a thought. What is your opinion?

TG: I think common ground or common bond is a good thing to emphasize but I don’t know that you would represent it in your diagram.

KL: But do you think that the communication mechanics and dynamics should be represented in the 3D PSS?

TG: Yes, I do. Because I think that is all part of problem solving.

KL: What would you think would help from a representation? Right now we have the one stack and that’s going to be either a SME or BS. I think one of the things that we haven’t gotten to yet, because this is just model 1, is you have two different SMEs which can bring different knowledge bases, different experiential bases and a BS who again brings yet a different set. From a symbology perspective, which you have broad experience with, numerous symbologies that you’ve used in the workplace - Would it make better sense to have one SME represented with one set of symbols, a second SME with a different set of knowledge bases and experiential bases represented with a second set of symbols and the BS represented with a third set because they are all different and separate entities? Would that make sense?

TG: That would make sense to me. Also, if you wanted to get more granular you could overlay over the top components – mechanical, dynamic, or whatever components – that all involve working in this problem space. That, in my mind, is more of a 3D PSS, whether you’re using VISIO on a 2D picture by adding layers you’re adding depth to that picture.

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KL: Well, we'll have to think about that. Maybe we'll circle back around and consider what we need to do to the model to represent it that way because I hadn't thought about that.

TG: Looking at this model <the Copeland and O'Connor model>, they are concentric ovals. They, with using the shadow effect on it, have given you effective depth.

KL: Yes. It is interesting that you bring that model up. It's an interesting model to me and having spoken with the authors of the model, they had a much more complex set of diagrams for that model but then it had to be deconstructed because the publisher wouldn't accept the model as it stood with the additional layers on it. Looking at that model <the Copeland and O'Connor model>, because I asked you what was your impression of the model, when I looked at the model initially, to me it looked the only portion of knowledge or experience or whatever that that person that was being represented in that PSS would allow to be utilized by someone else would be the outermost ring.

TG: <shakes head in agreement>

KL: Because everything in that model to get to the next layer, you have to go down quite a bit of depth to get to that next layer. And again, you have a boundary that you have to pass before you can get to that in that model. When you're in PSS, the piece that I like about this is that, granted there's going to be different sizes but everything is accessible because it's stacked, like a set of blades, in a RAID array. And, all the IT stuff aside, like access and security, if you've got the RAID array, anything in there is accessible, as fast as any other piece, it's all there for you. Where with this

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model, which depicts the individual, it says to me – only that outer piece is what you're going to have access to - and you still have to pass a boundary – and to get to anything else, it's very much peeling back the layers of an onion but each boundary has to be crossed. So, to actually get to the point of the innermost circle, you have to span a lot of boundaries just to get to the core. Not saying that isn't how many people could be represented, SMEs or otherwise. But in projects today especially where you've got big projects, you're working with people that you've never met, or maybe in a virtual space, and not to say that projects don't move from PSS to problem failure space – we all know how projects can go south – but what we're trying to represent is how can we demonstrate that people have access to everything and it is a positive environment. I'm looking at this critically from a representational and symbology perspective….

TG: I'm seeing this as a triangle. We have mechanics, dynamics and communication <points to each corner of a triangle> being the three outer boundaries of this triangle. Then the SMEs, with whatever symbology you choose for them, being in the bottom corners each and the BS in the top point because, again, they are working together in this space.

KL: <I drew what was being described.> So, did I represent this correctly?

TG: Actually, I was putting SMEs where you were putting mechanics, dynamics and communication. Within here <inside the larger triangle>, the BS, the SME <1> and SME <2> because they're working within that. That's how I envision it.

KL: Umm hmm. <agreement>

TG: Remaining within those boundaries, "the bind" connects those three. I see it as "the bind" or connectors…

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KL: <drawing> Connectors like that?

TG: Yea, everything working together in harmony.

KL: Yes, because this is the PSS, not the problem-failure space <chuckles>….

TG: Yes, working together in harmony to solve the problem. Yes, even two sets of triangles is effective as you have there….

KL: Yes, I just included the arrows

TG: What you have there, these would be your binds, these would be your connections or connectors. If you break a connection, you leak out <chuckles>…

KL: It's interesting because the connection BSIP2 was saying in our previous conversation that we need to think about including some of the universal symbols for communication and that whether it's email, IM, cell phone, a head for face-to-face…

TG: What I call face-time….

KL: I don't know what WebEx is – maybe the globe – those are all things that could then be represented within the confines of this to say when the connections are progressing as they should, then all of this should be working and heating up but when this doesn't work that's when the connectors start breaking.

TG: Right.

KL: And the connectors aren't just about the communication piece. Again, this is great because this connector could represent the communication connectors, but there is trust, there's shared context, there's, I don't know, environmental factors….there's any number of connectors….

TG: Team work…

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KL: So, there's a lot of things that could be represented as connectors. So that if any one of those fails and a connector breaks this <the model> starts falling apart. And we can have these folks represented like that <symbology modification to indicate three different individuals, groups, etc.>

TG: or even a single one, a single server which is the embodiment of that component, the SME or the BS….

KL: I like that. I have to draw pictures; I just have to draw pictures. That really helps me. I think some of the environmental factors that one of the BSIPs and I had talked about was noise. And I think he did a really good job talking about interference. And we've talked about packet drops where you don't get to hear everything - and you don't always know why – but that happens. I think the other thing that noisy environments can produce – for example, a less noisy environment would happen between you and I if we had, say a very long-standing working relationship in a project together. There's a lot less noise because what you say, I understand; what I say, you understand.

TG: Right.

KL: But too many times, people consider it noise if they don't consider it valuable. And I think one of the things we always forget is that we don't help people understand in this kind of an environment what the value-add is for the information we are trying to communicate. Obviously, one person isn't talking, typically, to expend hot air; in a project environment, you don't have time. So if they are communicating to you they feel what they are communicating to you is valuable. We haven't explored this but I know a lot of the projects you've been on, you've been working with a user population

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that has a very dissimilar experiential base as compared to you. How do you resolve what they're telling you as to whether it adds value to your understanding of the problem instead of filtering out and saying… <makes a gesture with her hand flying over her head>… this is just noise from a user that just cannot do their job. From a connector perspective, we've started listing some of these things and I'm wondering how do we represent "lack of noise?" which is typically adding value because the less noise the more connectors, the more connections, whatever we call this… connectors.

TG: There's different kinds of noise, from my experience. One of my BSIPs talked about the noise from the environment, where someone can only hear part of the message. You're asking me - how do I deal with users who may or may not have a level of experience to communicate what their issue is. In the case of a user, feedback is, I think, essential. You tell me "My email is not working" – that's all I know. I then ask you some questions and based on your responses maybe I can narrow down what the problem is. You tell me, "I don't know, I just log in and nothing happens." That tells me where to start looking, is it a connection issue to the email server, is it a connection between your workstation to the network, is the machine frozen, is the software corrupt? – a lot of different possibilities but at least I have a starting point.

Other kinds of noise might be in a work environment situation where in the PSS an individual or IT member may actively passively-aggressively sabotage things. I'll give you an example: we were tasked with refreshing machines in a number of different sites. We worked in 20 sites, some of them had hundreds of machines that we were replacing. So a team of us would go in, usually 5 - 7 people, and cover the site and, hopefully, replace everything in one day. We had one team member - at the end of the

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day, we would have to give a report of how many machines we actually did and the average was 20 – 25 per person. But we had one team member that consistently had one machine. And so that's a passive-aggressive action to try to… his whole purpose was to get out of being on a team.

KL: Obviously!

TG: And we discovered over a short period of time that the machine he had done work on was not done correctly.

KL: Oh, dear; even worse.

TG: So, we had to go back and fix it. And the team got together without that individual to discuss the issue. So, what was decided was that someone at the end of the day would go back to the machine that he worked on and fix the problems before we left. And he was not excused from being on the team. After a while, he started picking up his speed because he realized he couldn't get away with it. That's noise! He was creating interference.

KL: So, let's talk about other kinds of team noise. Noise is important if we have to represent it in the model. If a team is coming together, whether it is a SME or SMEs, groups, and a BS, when they are coming together there's a lot of noise from the team forming, storming, norming process. How would we represent that noise differently or should we? That's supposed to be activity that will help people build trust and shared context…. But is that value-add noise? If it's value-add, then it's not noise. But a lot of it I think could be considered "noise." Or maybe it shouldn't be considered noise because people are trying to move to a place where they are moving up that curve <the team-building curve> to become a team. What about that?

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TG: Well, again, going back to the BS, I see that person again being the facilitator, the lead more or less coordinating the various actions, achieving the milestones, whatever. But it all boils down to communication. So that noise, actually if it is going to be there should be in the communication area.

KL: OK.

TG: Now as far as the individual team member that is actually tying to interfere for his own personal gain, that's a control issue and that needs to be addressed. We addressed it at the local level so it didn't have to go up to the project manager. But if the project manager becomes aware of it then that person needs to take control; otherwise, he's going to lose control. Noise and control, I think, are interrelated to a certain degree.

KL: Interesting. Yes, you're going to have to shut things down that are sapping time and energy away from the team to redirect that time and energy into more productive processes. Again, I go back to this - you're in a PSS, not a problem failure space. And the piece I like about this third dimension, that my primary BSIP talks about is looking at this person in the Non-Deterministic Model they bring breadth and depth in various knowledge and expertise areas to the PSS. And the other SME does and even the BS does but until you bring all of that together and you start seeing that covalent bond, that electron cloud where things are really starting to come together and happen, sparks are flying… that's what he thinks about from this third dimension… that's what he sees as this problem solving space. Where things are actually happening in the PSS, you're actually developing a problem solution in the PSS. I like that; I'm getting a clearer picture of that.

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TG: When I originally read about the PSS, and you had mentioned context, I saw height, width, depth. SME 1 was height, SME 2 was width, and the BS being the depth.

KL: <draws as TG speaks> Hmmm. Interesting.

TG: And in the case of the triangle, I actually see that as a pyramid.

KL: Ahhh. Very important, all my scribbles <laughs>. I'm going to have to re-render but that's ok, that helps a lot because then you can see...

TG: Because we're talking about space here, we're not talking about a flat plane.

KL: Well, that's one of the things that one of the BSIPs had said which caught me once I re-read the transcript – he had said "you have to be able to bring everybody into the same plane." And I'm not sure that that's really necessary. You need to bring them into the PSS but when I think of plane I think of 2D, flat.

TG: X and Y

KL: Yes and that's all, and I thought I'm not sure that that's really where we need to be.

TG: Yeah, we put in the Z.

KL: So, with respect to the pyramid, we've got mechanics, dynamics and communication and then coming up <gestures to the pyramid peak>, is there a top point?

TG: Mechanics, dynamics, communication is the top point

KL: So, we've got another one going back this way <gestures to foot of the pyramid>

TG: Yeah….

KL: I just wondered because I agree this one still renders

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TG: If you wanted to go 2D, this one would still do it.

KL: Well, that's the headache, that's what we talk about

TG: The peak actually creates the space so that would be the work space.

KL: So the third dimension could be….

TG: The actual work space.

KL: Umm Hmm. Well, it certainly looks to be a pyramid like this.

TG: And that way you have the different entities floating within that space working together to solve that problem.

KL: Umm Hmm. You know, I think the representation – and I've pushed on this point - is very, very critical because every person that looks at this model <points to the Copeland and O'Connor model> or this model <points to model 1> or that model <points to the pyramid just drawn> brings a very different perspective to it. And if it's going to be Non-Deterministic, we have to make sure that what I see when I look at this <points to the Copeland and O'Connor model> which is peeling back the layers of an onion actually takes a lot of effort to get to the heart of things… that's not typically the luxury you have in the PSS for big projects. Or for small projects, even, today! In the virtual space, you have PSS with SMEs and BS coming together from all over the world and they try to problem solve. And as much as it would be GREAT to have all the face time that you want, to get to know people and share with them, a lot of time you just don't have that kind of time. So, that's why I am trying to look at the symbology and the representation because I don't want people thinking like I did with this < points to the Copeland and O'Connor model>, this is going to require really a lot of effort to get past those boundaries to get to the inner….

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TG: Well, I think a lot depends on the problem. There are some problems where I have an issue with a piece of software that is not functioning correctly. I have exhausted all the local sources of information so I have to pick up the phone and call the software vendor who then transfers me to somebody in India who then remotes in to my machine and a few keystrokes away fixes the problem. When the problem is fixed and verified, we say goodbye, we're done. That was a short-term problem. Versus we want to build a data center in the middle of the Mojave Desert…

KL: Oh, my! That's a big one!

TG: That's a big one because we have to bring the electrical to the site, we have to provide a building, we have to provide all of the infrastructure, we have to provide all the human necessities….

KL: Major cooling!

TG: You know all of those issues so there's a lot more problems there requiring a lot more SMEs.

KL: Right. You need a lot more expertise to bring to bear on a problem that size as compared to "something is not working in this application or on my machine or whatever."

TG: So, again, it depends on the complexity of the problem. What you're putting together is a starting point model, I think, which is expandable to any level of problem.

KL: That's exactly what we're looking to try to do. Because I've only looked at trying to put what I consider to be the base, core, of a team together. To my mind that would be a boundary spanner and two SMEs, not one SME. Because the reason you need a BS is to bring the two separate groups together in a more efficient, more

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effective manner. Because the BS has some aspect, some significant expertise, knowledge, experience with this group and he knows that there's going to be a gap working with that group. Or maybe he doesn't know, maybe somebody higher up on the chain, in the hierarchy of the organization says you know this person has worked in this kind of an environment, he's worked in that kind of an environment, we've got this problem and we need to bring these two groups together – I think he could help, to use your word "facilitate" the team-building and the translation, building a common taxonomy, helping them develop a shared context, shared language….because teams have their own language.

TG: Umm Hmm.

KL: Making sure that they understand the symbology….

TG: OK, here's a working example. My software doesn't work anymore. I'm SME 1. I call the vendor; the vendor brings in the guy in India. We end up communicating. The vendor may or may not be on the phone. As a BS, he connected me to the right person.

KL: I think that's really important, what you just said, because as a SME you already have a significant level of expertise and understanding when it comes to the problem itself or you could not ask the question to the vendor using appropriate language so that he knows how to correctly direct you. I think that's a very big distinction between an end-user who does not have the knowledge or understanding and can formulate a very poor question as compared to a SME who can formulate a very clear question even if it's not something that they know how to solve themselves. They have sufficient semantics and knowledge that they can formulate a very good

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question. And then going to a BS, the BS can pick up the pieces in this question and determine, Ok, Microsoft's not going to help, this is going to have to be an Oracle guy, and specifically, it's going to have to be an Oracle guy that knows Java to help this person. And then, working with that you can direct them and put the SMEs in place and then you <the SME> also gains as far as their knowledge base.

TG: I can give you a worse case than that where I spent 18 hours on the phone trying to solve an issue with Exchange where I called Microsoft and Microsoft gave me…let's see where did I start out at? I started out in India and from India I went to Russia and from Russia I went to Germany and from Germany I went to Canada and from Canada I came to the US. Each one of those people could solve various parts of the problem until we got Exchange back online 18 hours later. It felt like my headset was glued to my ear!

KL: 18 hours! Oh my goodness!

TG: Again, that's a real-life example.

KL: And that's exactly what we're looking for, that's exactly the kind of work….because you're a SME in your own right. Not saying that you cannot act as a BS in situations where you have that capability to bring two sets of SMEs, individuals, teams, groups of individuals together but there are times where you actually have to take your knowledge and ask for a BS to intervene whether it's directing you to the right resources or whatever. That's a very clear example. I'm just double-checking all of my questions… anything else that you'd like to add because it looks like I've covered everything that I've needed to….

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TG: In my own mind and experience, trust is a big thing. Trusting the information you're getting, trusting the SME really IS knowledgeable…

KL: How do you assess that?

TG: Depends on the situation.

KL: Obviously, communication.

TG: In the case of the 18 hour deal, the guy in India that I was first talking with… first of all , I could barely understand him….

KL: So you had no real concept if he was knowledgeable or not.

TG: Right…

KL: If there's that much of a barrier with respect to language or heavy accent or what have you…again, it's interference. It's noise…

TG: It's noise. And it's not negative, not on purpose, it was luck of the draw in that case. And then I was handed to another guy in India who was less knowledgeable but was smart enough to transfer me to the guy in Russia because it was beyond his ability. The first guy tried several times, and I worked with him almost an hour before I said I really have to talk to someone I can understand. I didn't want to be mean to him, but – I can't understand you! We're not getting anywhere and we need to solve this problem now! So we just progressed from there. The guy in Russia was also difficult to understand but at least I was familiar with his accent and I could pick out most of what he was saying. When I got to Germany, he was very easy to understand, heavy accent but easy to understand. And then, Canada, of course, no problem and US, of course, no problem. It's been interesting as there have been times when I have been transferred to someone in the US and they have a Russian accent.

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KL: It's always amazing to me how many international people you deal with here within the IT industry. It always surprises me how many times they are put into support-type activities but the corporation hasn't put them through any sort of linguistic support – speech classes - so that they help them get past a heavy accent which truly limits their usefulness as SME. If that two-way communication isn't there, it's a real problem. I'm always surprised that sort of support doesn't exist. We have other employee programs that are available to you but that's not one of them. And it's crucial because it's part of the communication that you have.

TG: In my present job, I'm learning to understand the Indian accent because half of our developers are Indian.

KL: But again, India is such a big country, like the US, it's interesting how the accents change depending on where they're from. It's very marked in some instances.

TG: And how long they have been here <in the US>.

KL: Yes.

TG: It makes a big difference. Are we done?

KL: We are done; thank you so much for the time!

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