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The use of metaphor in systems engineering practice: a preliminary sociological study

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Abstract

This exploratory study leverages representative metaphors that the author collected during his tenure as a systems engineer in the defense contracting industry to consider the roles metaphors play in systems engineering practice. Preliminary conclusions center on the metaphor's ability to render (not reduce) complexity/ambiguity, its ability to build social bonds through humor, and its role as a tool to creatively understand unique work contexts. Ultimately, however, the invention and reproduction of metaphors by the engineers helps to reveal the underlying nature of systems engineering work and its underlying technical, social, and political currents. Implications for research and practice are discussed.

Keywords: Work Studies, Systems Engineering, Metaphor, Technology, Social Psychology, Rhetoric.

Introduction

In a recent article, IEEE highlighted the role that metaphors can play in understanding complex engineering problems (IEEE Pro-Comm, 2019). This move to impose powerful metaphors onto phenomena from the outside has great potential and has already supported a vibrant discussion of its role in sense-making and design in technical environments (Geirbo, 2017; Ortony, 1979; Boland, 1987; Kendall & Kendall, 1994; Aanestad, 2002; Parmiggiani, et. al., 2016) as well as in teaching (Pitcher, 2014) and in grappling with societal-level phenomena (Coeckelbergh, 2010). Furthermore, Gideon Kunda's classic ethnography *Engineering Culture* makes many references to metaphors with respect to how engineer's experienced identity and control in a hi-tech company (Kunda, 1992).

However, despite scholars' calls to understand how technical work is actually performed in practice, few have met this challenge (Barley, 1996; Barley & Orr, 1997). This challenge is important, however, as many theories and paradigms make simplifying assumptions about how work is actually performed and how non-technical factors influence performance as well as the phenomenology of organizational life.

This paper attempts to fill some of these gaps by gathering and analyzing metaphors used by systems engineers in practice – used in the work activities themselves.

Setting and Method

This study does not follow a rigorous qualitative or quantitative methodology. Nor is it a case study. Rather the author enjoyed a twenty-five year career as a systems engineer in a large defense contracting plant working on Navy programs and has recorded metaphors that he has witnessed and used himself in the work activities. The organization is a professional bureaucracy employing over 1000 managers, engineers, and technicians. It has a matrix structure in which functional departments provide engineering services across multiple programs/DoD customers. Therefore, while no rigorous methodology was used to gather or analyze the data, nonetheless the author was able to compile a representative set of metaphors and the contexts in which they were used in this setting and which serve as the basis for an exploratory study of the role of metaphors in the practice of systems engineering work.

The study falls within the Interpretivist philosophy of research in which meanings are viewed as socially constructed though actual interaction and exchange among participants within interpretive contexts (Mead, 1934; Wittgenstein, 1953; Berger & Luckmann, 1966; Blumer, 1969; Geertz, 1973; Goffman, 1959). Therefore, in this study the more traditional scientific goals of quantitative prediction and generalization are traded for the scientific goals of understanding and explication (i.e., ontology) of social phenomena.

Data

In the sections below I identify metaphors that were routinely invoked in the systems engineering work. I provide enough detail to appreciate their meaning and their context. This will serve as a basis (empirical data) for reflection and synthesis in the analysis section to follow.

"Motherhood" and "housekeeping"

For those who have experienced life in a systems engineering environment, the one universal is documentation. What systems engineers "do" is write. These writings capture requirements in specification, architectures and designs in design documents, test cases in test documents, etc. While the intended audience for each of these documents is interested mostly in the technical content of them, nonetheless it is important that anyone who runs across the document should be able to understand at least what the document is about even if they cannot appreciate or understand its contents.

Therefore, most document templates/requirements include some "identification" section at the beginning that most users of the document will skip over, but serves the needs of broader audiences. Thus, to the real consumers of these documents this content is superfluous and only there to satisfy less technical purposes. It is in this context that "motherhood" is used to attest that there is a layer of wholesomeness or goodness and caring that is being applied in the documentation. It is a simultaneous dismissal and comical embrace of content deemed to be there to satisfy the "house keeping" of crossing one's T's and dotting one's I's for non-technical stakeholders.

Furthermore, as engineering has historically been a male-dominated profession, one is less surprised that such these metaphors would leverage the traditional division of labor between men and women in a household context.

"Dropping balls" and "shaking trees"

Scholars identify three different types of task interdependencies (pooled, sequential, and reciprocal) (Thompson, 1967). In pooled, each contributes to some measurable performance parameter that all depend upon for success. For example, with the exception of relay races, track competitions involve individual contributions that are tallied to a total relative to other teams. In sequential interdependence, like the relay race, or most plays in football, there is a division of labor and one role occupant relies in the inputs of others in order to do their task. In reciprocal interdependence, in contrast, the inputs and outputs shift, as in a "give-and-go" in basketball. Each role occupant is versed in many plays and the goals are met when actions are being successfully swapped and interchanged.

In all three instances, there are times when desired goals (from the stakeholder's point of view) are not being achieve because one of these interdependencies is failing. In an engineering environment (especially those in large matrixed organization), "resources" of schedule of and budget lead to uneven flows of supply and demand for the work required to fulfill an interdependent obligation. There is also a general cultural assumption in most engineering work contexts that everyone is doing their best to fulfill their obligations and that it is a natural and expected state of affairs that some tasks upon with others depend might not be completed when needed. To the extent that blame can be attributed to these failures, it is referred to as "dropping the ball."

Whether it is the actor referring to their own ball drop, or those depending upon the task completion claiming an engineer on whom they depend has dropped the ball, it is usually non-critical and more along the lines of admitting that with limited resources this simply "happens."

Given that this simply happens and is systemic in professional bureaucracies, what is one to do about it? Often with peer-to-peer interdependencies the dependent worker may feel they lack the authority to approach the ball dropper and request it be picked up. After all, in a matrix organization with functional departments, the interdependency is often an interdepartmental affair. Therefore, in this situation they will refer the matter to their superior who will then reach out to his or her departmental peer and "shake some trees." At its root, shaking trees, makes things happen such as leaves falling. Therefore, shaking trees in an engineering context is a relatively amiable (the department manager is not criticizing the other department, but rather communicating the dependency) and reprioritizing the engineer's tasking.

"Is this the rock you want?" and "sniff test"

Although systems engineering processes are objectified, standardized, and documented to the extent possible, nonetheless systems engineering tasks involve technical, political, and social expectations that one will not find in documented processes. Indeed, if one were to argue for what the system engineer's true "value-added" is to the community in which he or she is embedded, it is perhaps the ability to navigate the complexity of these diverse expectations to arrive at an acceptable solution.

The systems engineer, therefore, must be feedback seeker. From a controls point of view, if the engineer is not constantly seeking out feedback for the technical, political, and social dimensions of his or her task, then beyond the "ball being dropped," the product will be unsatisfactory.

As a systems engineer myself, I have a particular intimacy with the feedback metaphor "is this the rock you want?" Whether I was the engineer responsible for the product or expecting a product from another engineer, it is a routine occurrence that the criteria for evaluating the product is often decoupled from the expectations for the product. In other words, one cannot articulate what it is that they want with any specificity, but one will "know it when one sees it" as to whether it is satisfactory. Therefore, one is given relatively diffuse direction for what is expected and is left to taking "stabs at" producing an artifact. The evaluator will then tell the engineering that the artifact is unsatisfactory and reasons why. It is only after several iterations of this "is this the rock you want?" cycle that there is a convergence on the correct product. It is an acknowledgment, first and foremost, that given the complexity and the ambiguity of many systems engineering tasks, that converging on what is "acceptable" is a dynamic process that involves some trial-and-error and communication/reporting – not unlike the core principles of Agile development.

In parallel with seeking feedback in this way, a systems engineering group will often need to obtain some assurance that their design is progressing in the right direction before any kind of formal review. The term "pass the sniff test" is often invoked to acknowledge that there could be some elements of the design that stakeholders might find unsatisfactory and that the design team had not anticipated. One of the key functions of the sense of smell is that it can instantly detect whether something is "off" with food one is about to eat. Therefore the sniff test for the design informally determines earlier rather than later if there is something awry with the design that would likely be embarrassing if identified in formal documented review. In a group context the metaphor "dartboard to throw darts at" is often invoked to signify a similar dynamic in which one invites informal inputs in early phases of a design/product.

"Gold-plating" and "belt-and-suspenders"

In the more than twenty-five years that the author was a systems engineer, he worked on many different defense contracting platforms and customers. While all programs and customer expect high quality products, there is variation on what is considered to be acceptable quality.

"Gold-plating" is a metaphor that applies to ideal levels of design, documentation, testing, and thoroughness culturally ingrained in some of the defense systems where failure cannot be tolerated and the customer expects (and is willing to pay for) perfection. It is interesting that in my career as a systems engineer, this term only surface when it served to provide contrast to newer programs that could tolerate less-than-perfection and were managing stricter budgets. As systems engineers moved from one program to another, they would often be met with comments such as, "Oh, you're coming from program X where they gold-plated everything, but you won't have to do a, b, and c on program Y." Again, this is not to imply that poor quality is acceptable, rather that the layers and layers of often process imposed to achieve perfection in a gold-plated program are sometimes unnecessarily burdensome and costly.

The metaphor "belt-and-suspenders" is frequently applied in these settings. It is used to acknowledge that there is a design feature that is functionally redundant (as both belts and suspenders function to keep one's pants from falling, to have both is comically redundant). In most instances this would be applied to communicate that one of the redundant features is unnecessary and should be removed from the design. However as argued in the previous paragraphs, sometimes redundancy is not a bad thing and is purposely introduced or maintained in a design to achieve higher reliability, fault-tolerance, and security. Indeed, redundant subsystems, RAID servers, and defense-in-depth are all design philosophies that rely on redundant layers of functionality to achieve robustness.

Standardization: "Templates" and "boilerplates"

Engineers, when given a new task, rarely start "from scratch" or "in a vacuum," but rather are defining requirements or designs for a new iteration of a system and therefore will seek out documentation from the previous iteration as the starting point. This greatly reduces the degrees of freedom for what is expected along both the lines of structure and content. To the extent that it helps with structure one encounters templates. Although the term "template" itself is not really a metaphor like the others I have discussed, it nonetheless functions *as* a metaphor in engineering settings. Although the content for requirements in a specification are expected to vary, templates provide standardization for *how* they are to be presented.

In concert with templates, certain content is expected to be presented in a consistent manner across documents. These may entail information about acceptable use of the document, security aspects of the document, standards and official documents applying to the focal document, etc. Therefore, in contrast to motherhood which imposes non-technical content in the document, rather "boiler-plating" introduces required technical content that applies to the system being documented.

"Water cooler talk" and "jump balls"

Organizational structures, cultures, schedules, meetings, etc. go a long way in terms of defining purposeful communication in pursuit of collective goals. However, at times there is serendipity arising from chance encounters between engineers that represents a separate channel of communication that may be impactful. "Oh, it's becoming apparent from water-cooler talk that department X is now aware of what department Y is trying to do," or "You don't want the workers to become aware of the benefits changes from water-cooler talk before they hear it officially from HR." Although water-cooler talk can also support the cultivation of social relationships between employees, it is also invoked to emphasize the fragility of keeping secrets, hidden agendas, or official decrees.

Also, social in nature, the metaphor "jump ball" is used to denote a situation in which management strives to elicit inputs from engineers in an unstructured power-neutral manner. "Well, as we're realizing how COVID-19 restrictions are impacting workers in and out of work, I'll be holding a jump-ball meeting to get ideas on how we might improve worker engagement." Therefore "jump-ball" emphasizes both that individual participation is encouraged and all are on equal footing with respect to their status and potential contribution.

"Hurry up and wait"

As we saw the metaphor "is this the rock you want?" complexity, uncertainty, and ambiguity also operate in the temporal dimension. With the sequential and reciprocal interdependencies weighing on role occupants, it is not uncommon for managers or engineers to pressure an individual or group to be present at a meeting or to supply a product or artifact by a certain date, only to discover that once compliant, the apparent urgency has abated and the requestor is not at *their* meeting on time or for reciprocal tasks is slow to respond (do their part) with the inputs. It is a compact expression of frustration that, "well, they made me bust my butt but I guess it wasn't so urgent after all."

However, as with the rock metaphor, this is not so much the consequence of the tasker being inconsiderate as it is the reality that time, as a resource, is often scarce and that in juggling multiple and often conflicting demands, priorities are always shifting and these situations will routinely occur.

Analysis

The variety of contexts and problems in which systems engineers choose to invoke metaphors, even the few that I have considered here to be "data," compels us to see that there is no on-size-fits-all theoretical framework within which to place these data. This validates those scholars who claim that the richness of the work itself transcends attempts to simplify it with parsimonious theories (Barley, 1996; Barley & Orr, 1997).

Characterization of Complexity/Ambiguity

That being said, it can be argued from the data that one function metaphors tend to play is not necessarily to reduce complexity or ambiguity, but rather to render it understandable. The metaphors acknowledge and describe via analogy the relevant nature of the complex technical, social, and political realities systems engineers must navigate in order to perform their duties.

It is precisely because of this that metaphors are powerful because in capturing a truth about an infinitely complex world, they can aid in understanding that world, organizing that world, and communicating that world to others.

Perhaps much more could be said here about how a particular metaphor leverages induction or deduction from available information in order to be effective. Or how some are used in a purely interpretive way or in a purely communicative way. However, for this exploratory analysis, the metaphors that work and become acculturated are those that in some uncanny and clever way are able to capture and fully appreciate a truth relative to a complex world.

Affective/Social Functions of Metaphor

Although not made explicit in every instance of the data, the reader can recognize from their own use or witnessing of metaphors like these that their delivery is accompanied by a chuckle and a comical appreciation of their fitness to a technical, social, or political truth reality. The metaphor will often frame a particular group and its tendency to be such and such a way that is not always flattering, but nonetheless reinforces who and what they are.

As such, to the extent that the metaphor is delivered and received comically, it may serve to build emotional bonds between workers as well as reinforce (or at least clarify) cultural categories.

Systems Engineering Practice

Perhaps most importantly, the data reveal that metaphors hover around many facets of the work that engineers perform and makes it clearer to all involved as to what is going on at a particular moment. When crafting a document a coworker may advise you one way or the other as to what “motherhood” or “boilerplate” to use and in so doing remind you of what these mean and why they are relevant to the task at hand. Or as you tell your superior or mentor what you are planning to do for your scope of work, they may invoke the “gold-plating” metaphor to impart to you that the scope is excessive (or not excessive enough). Or to save face an engineer or department may have a first cut at a design concept and will ask “is this the rock you want,” or obtain a “sniff test” on it before formally moving forward with it. Examples of how each of the metaphors can be used in the actual work flow could be provided here, but point is that not only do they characterize a complex world without necessarily reducing it, but they also are tools ready-at-hand in the flow of the work to avoid potential issues and to arrive at a product that meets the various and sometimes conflicting sets of technical, political, and social expectations.

Discussion and Conclusion

The analysis stresses that in the use of metaphors in complex work environments such as systems engineering it is unlikely that there is an existing theory that would parsimoniously capture its *function* in organizations. I believe that the closest we can come to that, given this realization, is that like any word or phrase used narratively/rhetorically in a particular context, it has a meaning that remains embedded in (or solely arises from within) that unique situation. In this sense, these finding align with the basic tenets of Symbolic Interactionism and in particular Erving Goffman's dramaturgical approach to analyzing the social world (Goffman, 1959). In other words, the meaning that a particular metaphor conveys may be captured to some extent by the metaphor's primary elements (belts, suspenders, darts, or sniffing noses), but these take on meaning as they become *matched* to actual actors, groups, documents, etc. It is this creative matching that seems to lie at the heart of their usefulness, why engineers use them effectively, and why, at the end of the day, they offer some comic levity to an otherwise linear or objective communication.

Therefore, to ethnographic scholars of organizations, this exploratory study may help to think of workers as creative sense-makers whose actions are not programmed by existing cultural and structural factors. Indeed, the use of metaphor is highly creative and effective and contributes, phenomenologically, toward an experience of organizational life that offers humor and builds bonds of friendship and mutual appreciation.

To practitioners, this study is not intended to try to encourage a program in which one can cultivate the effective use of metaphors in an organization with an eye toward increasing productivity. Rather, as a practitioner one is already immersed in a world of metaphors and the meanings they imply and infer. In this sense, this exploratory study may help to deepen an appreciation of what metaphors are and how they contribute to the culture and climate of the organization.

As previously stated, the goal of this study is not prediction and generalizability but rather to begin to identify and explicate a phenomenon that so far has received little or no attention. Metaphors are used in the flow of social interaction as a highly sophisticated form of rhetoric that cuts to the essence of interpretation and expression in complex technical, social, and political environments. Nonetheless a more systemic data gathering methodology and quantification could be helpful in understanding which social/work settings use metaphors relatively more or less and the contributing factors (e.g., culture, size, complexity, occupation/profession, social structure, etc.). The creation and mimetic propagation of specific metaphors could also be an interesting line of inquiry for future research. For the current authors, however, the desired next steps are along the lines of a more systemic ethnographic data gathering effort that will provide data sets amenable to understanding the rhetorical foundations of metaphor in technical settings.

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