17th ICCRTS
"Operationalizing C2 Agility"

The POET Approach

A collaborative means for enhancing C2 systems engineering

Topic(s)

Topic 2: Approaches and Organizations
Topic 1: Concepts, Theory, and Policy
Topic 4: Collaboration, Shared Awareness, and Decision Making

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***Abstract*— There is a gap between the current command and control (C2) systems engineering (SE) state of practice and the need for agile, holistic solutions. Highly motivated adversaries rapidly adapt to exploit gaps not only in our technologies, but in our organizations and processes. Nevertheless, SE efforts focus heavily on the optimization of single systems for specific, pre-defined requirements. Moreover, SE often ignores important *political, operational, economic, and technical* (POET) factors that can make the difference in a program's success.**

This paper outlines the efforts, findings and approach of a three-year research project aimed at improving the engineering of information systems. The POET Approach put forward in this article is primarily focused on exchanging our current set of serial, disjointed SE processes for a collaborative co-engineering approach in which stakeholders, the broad range of people, from end users to senior leaders, with a direct interest in the success of the project, engage in developing shared understanding of the trade space that occurs at the intersection of people, processes, organizations, and technologies.

Keywords: Systems Engineering, Collaboration, Shared Awareness, Shared Understanding, Consensus, POET, political, operational, economic, technical

I. Introduction

The U.S. government's traditional systems engineering (SE) approaches were born in the industrial age to design and create complicated products (usually hardware) within a largely predictable and controllable environment. The core pattern of these SE approaches is to develop a direction for a project and then deconstruct the effort into component activities that can be solved either independently or in series, as the dependencies dictate, to accomplish the project's goal. This kind of approach works well for large, but relatively static SE efforts. The Apollo program would be an exemplar of this approach. As these approaches were developed, the government also fostered the tools that would be required to efficiently track and manage the many activities that such a distributed process would take (e.g., Integrated Computer-Aided Manufacturing). [1]

The largest of the U.S. government's acquisition efforts happen within the Department of Defense (DoD) where yearly total procurement costs top $1.5 trillion.[2] The U.S. DoD's core acquisition process, which encompasses its SE processes, is commonly known as the *Defense Acquisition System*, and it is governed by the *DoD 5000 Series* policies. DoD 5000 is employed to govern the full spectrum of defense acquisition from aircraft carriers to software systems.[3] Although the system has its general faults, it has recently been called out as particularly wanting with respect to the development of information technologies (IT). Both the Defense Science Board and the National Academies published reports that recommended broad systemic changes for the acquisition and systems engineering of IT.[4][5]

This paper summarizes the efforts of a three-year internal research and development project at the MITRE Corporation to investigate both the conditions that are causing widespread SE problems and innovative means for addressing these issues. The project was born out of a series of observations that SE efforts were failing or underperforming for reasons that seemed to be elusive for the current processes. The approach we have developed is entitled POET for the broad *Political, Operational, Economic,* and *Technical* aspects associated with each systems engineering effort.

The designation of the POET factors is designed to characterize the various forces on a program or effort in a complete but simple fashion. Following are brief descriptions of each factor area.

- Political - The political factor is intended to encompass the interactions between people and organizations as they exercise power and authority in the context of a program.
- Operational - Operational factors are those that have to do with the execution of processes and activities among people.
- Economic - Economic factors are those that have to do with the distribution and consumption of money and scarce resources (e.g., labor, office space, funding).
- Technical - The technical factor is comprised of those issues concerned with the production and employment of various technologies.

II. Motivation

The DoD 5000 process can be illustrated as a linear flow (Figure 1, DoD 5000 Defense Acquisition System) with a number of phases and "milestone" decisions that govern the process. The hard work, with regard to systems engineering for information technologies (IT), in this approach is assumed to be in solving the problems associated with the technology, and if it is done correctly, it is intended to result in a successful outcome.

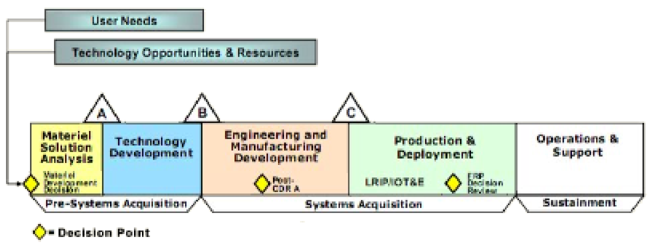

Figure 1, DoD 5000 Defense Acquisition System

Over time, this brand of SE evolved to better handle certain aspects that could be measured, predicted and controlled and that were perceived to most directly affect success. Conversely, those aspects that were harder to pin down or that had a less obvious causal connection were largely pushed aside. As a result, traditional systems engineering processes are fairly effective at handling the more objective Technical and Economic issues. They are less successful in handling Operational issues, and quite poor at handling Political issues.

All too often, despite the best efforts of talented people and millions of dollars in resources, programs are slow to recognize and respond to change, or become divorced from the end users' reality. As a result, the final product may not deliver useful capabilities, or the program itself is hobbled or canceled outright. Furthermore, the programs that are deemed successful often rely on the heroic effort or the "force of personality" of a unique program manager or an overtaxed team. Simply relying on managing the triple-constraints of cost, scope and schedule, or other established, and time-honored systems engineering processes may not address the full range of factors that can promote *consistent* success.

A. Observed POET Patterns

The seeds for this inconsistency tend to fall into predictable patterns. Specifically, research shows that programs tend to be relatively good at handling those aspects of a project that are both stable and accurately defined.[6] These two properties allow engineers, managers and technologists to practice the proven, standard approach of decomposing the larger effort into smaller steps that can be readily performed in a sequence. Those aspects that are not easily definable, or those that are not stable, do not lend themselves to effective decomposition and subsequently are not suitable for our traditional systems engineering approaches (e.g., waterfall development).[4][5]

Typically, the way we have seen this pattern being manifested in a project is that engineers can readily address *technical* issues as long as the requirements are stable. Additionally, our programs have tried and tested regulations and standards for dealing with the *economic* factors within an effort. Things tend to get shakier, however, when we move into the *operational* realm where the changing and elusive requirements of our users often cause wasted or misdirected effort. In the *political* realm, our systems engineering processes tend to be overmatched and the individual skills of the leadership becomes the factor in determining the outcome.

As one moves from the *technological (T)* to the *economic (E)* to the *operational (O)* to the *political (P)*, there are fewer means for quantitatively assessing the progress or success of activities. Additionally, it becomes more difficult to predict outcomes and maintain control as one moves towards the political. This happens for a number of reasons. As we move into operational and political issues, we shift from the world of the tangible and the observable, to the intangible and the perceived. In the technical realm, human-designed mechanisms and processes interact with the physical world in largely predictable manners. With respect to the political, SE issues are expressed in the minds of the those with an interest in the success of the program, or *stakeholders*, and are subject to the associated vagaries of human perception and action.

Although the technical world is complicated, it is deterministic and lends itself to the aforementioned deconstruction. As such systems grow in size and scope, they become increasingly difficult, but not impossible, to engineer with enough resources. The aforementioned Apollo program, for instance, was extremely complicated, but the inherent problems associated with it could be isolated and distributed among thousands of people, solved and then reconstructed to complete a successful whole.

The Operational and Political domains, however, suffers from the innate unpredictability and unknowability of humans and their actions. These social factors, when combined with other confounders (e.g., large program size, broad system scope, dynamic environment), tend to make deconstruction ineffective, and thus, render a system very difficult to predict or control through traditional means.

B. Complexity Issues

Even more vexing for systems engineers than the purely soft-side *political* and *operational* issues is the complexity that often arises from the interplay of two or more of the POET factors. Traditional systems engineering relies heavily on the notion of predictability – X inputs to our system will produce Y outputs. Complex POET interactions cause system behavior that appears to be chaotic, defies prediction, and renders even usually reliable approaches (i.e., *technical* and *economic*) ineffective. [7][8] Although our traditional systems engineering approaches are still necessary, they are no longer sufficient to deal with the complexity that our programs face.

Throughout the POET research project, we have looked for evidence of simple means or metrics for effectively dealing with the POET factors. Our research and experience have consistently led to the conclusion that the complexity of the problems that we face with respect to POET does not lend itself to simple solutions or metrics. In short, we cannot expect to identify simple ways to tap into and affect the political and operational factors. The interplay of these social aspects (with themselves and the technical and economic factors) is too complex to isolate and deconstruct.[9]

This inability to handle complexity in simple ways is described by Ashby's Law of Requisite Variety. It states that the larger the variety of actions available to a control system, the larger the variety of perturbations it is able to compensate.[10] Stated conversely, a complex system can be controlled only by a commensurately complex control system. Thus, when confronted with a complex SE project, we must agilely resort to solutions that have the variety of action to respond appropriately.

Much of this complexity lies in what Conklin refers to as *social complexity*, which tends to grow with the number and diversity of the stakeholders.[11] Systems that once would have been expected to be used by tightly-controlled groups of relatively homogeneous users are now expected to act as enterprise solutions that satisfy not only a broad collection of heterogeneous stakeholders, but have the capacity to support unanticipated users.[5] As a result, we must balance the needs and dependencies of a larger set of stakeholders to find solutions that are generally acceptable. To achieve this balance, we need to account for team dynamics and the tolerance of each stakeholder individually and as a group collectively to accept change.

C. Shared Understanding and Solutions

> ***"The 'Holy Grail' of effective collaboration is creating shared understanding, which is a precursor to shared commitment. If you accept that the crux of effective action is agreeing on what the problem is, then the challenge for organizations is coming to a shared understanding about what their particular dilemma is." – Jeff Conklin, P 15 [11]***

Two other particularly salient issues that we have seen in the POET arena are a need for shared understanding of problems, and a need for solutions that take into account the wide range of stakeholder needs. Without some kind of shared understanding it is difficult to frame POET problems in a manner where decisions and tradeoffs can be assessed in an effective manner. Once some shared understanding has been attained it is even more critical to develop solution sets that the stakeholders can support.

The difficult POET problems (i.e., Political and Operational) exist primarily in the minds of the stakeholders. They are abstract and often revolve around relationships and opinion. Different stakeholders can hold very strong, and very different, beliefs about the nature of the problem and the environment. There may not be a "right" version since these constructs are often not grounded in objectivity. Moreover, even when there is an objectively correct response to a situation, humans tend to make routine decisions from the gut rather than through systematic process.[12]

In any event, decision-making requires that we make sense of or "frame" the situation before we can take purposeful action, and teams must develop a shared understanding of both their problem space and their solution to be effective.[13][14] For large or heterogeneous teams making or coordinating around decisions, it can be quite difficult to share awareness, make sense individually, and develop shared understanding of the environment and the capabilities of the team to achieve what Klein refers to as the *Team Mind*.[15]

The prime importance of the establishment and maintenance of shared understanding among stakeholders makes misunderstanding and hidden agendas very hazardous for teams. Even if a stakeholder team cannot agree on specifics of the situation or even the goals, the stakeholders must have a basic understanding of where these differences lie. Such an understanding allows the team to act purposefully work towards solutions that are acceptable to a critical mass of the stakeholders. An understanding of the underlying goals of the team also allows individuals to *self-synchronize* and aligns their regular, daily decisions (that accrete to great effect) with the group. The military actively promotes this form of self-synchronization through the concept of commander's intent.[16] Solutions that do not enjoy the commitment of the stakeholders will likely be less effective because efforts will not be as concerted, or they may be half-hearted.

We have found that there are many considerations to take into account to satisfy this larger stakeholder group. For instance, understanding alliances among the stakeholder groups, identifying who carries weight with whom, and concluding as a result who are the critical stakeholders can be pivotal. Influencing the most critical stakeholders, from which others will follow, then provides one mechanism for alignment among stakeholders and progress to be achieved. Otherwise, unaligned stakeholders may undermine the greater effort in the pursuit of their parochial goals.

III. Activities

The research program has had three interdependent lines of inquiry: theory development, process development, and field study (i.e., experimentation and observation) in line with Nunamaker's information systems research framework.[17] By adopting this approach, we intended to triangulate on the elusive POET issues and potential solutions.

A. *Theory Development*

This research began with the acknowledgement that, as mentioned previously, programs were underperforming or failing for reasons that tended to elude the standard responses and explanations. As such, we started our effort with a brainstorming to name the broad causes that colleagues, the literature, and we, personally, had identified for such failures. We then clustered these into nine focus areas with the idea that the whole model would likely change as we gained more insight into POET issues. The nine focus areas that we identified were:

- Commitment – The degree to which stakeholders are dedicated to success
- Trust – The degree to which stakeholders feel they can rely on others
- Mindset – The way that the stakeholders view the program within the greater environment
- Situation Awareness – The degree of stakeholders' perception, and coherent understanding of the environment and its possible future state
- Cost/Schedule – The resources available to the project
- Complexity – The predictability and controllability of the project
- Agility – The ability of the project to rapidly adjust in light of exposed need
- Teamwork – The ability for disparate stakeholders to work together
- Demonstrability – The degree to which the value of the program is understood by those outside of the program (e.g., funding authorities)

Another means for gathering information for our theory development was through interviews with experienced systems engineers focusing on "*turnaround stories*". We framed the semi-structured interviews by asking them to tell us about a situation that they had personally participated in in which a program or project in trouble was salvaged. We found this approach to be quite valuable as it caused the participants to recall a discrete situation which allowed us to more easily separate the cause and effect relations of the turnaround than if we had simply asked about a failure or a success.

When we embarked upon the theory building work, we expected to find a relatively even distribution among the POET areas. It was a surprise when the data tended to show patterns of dysfunction heavily leaning towards the political and operational. When pressed to understand why, we noted the relative maturity of the technical and economic approaches and the lack of predictability and/or objectivity found in the political and operational spheres (as described above in Observed POET Patterns).

These data gathering efforts yielded a wealth of information that allowed us to forge a general framework and begin the development of the POET approach.

B. *Process Development*

Our ultimate goal with this project was to identify a relatively simple, scalable and repeatable approach for successfully dealing with the POET systems engineering issues that affect government programs and projects. Armed with our initial data and theory we looked for ways to address interpersonal and intergroup problems that defy conventional approaches.

Collaboration has been identified as an effective way to deal with complex "wicked" problems – those that cannot be easily defined or resolved through traditional means.[18][9] We determined that by building a collaborative POET approach that was simple and effective, we could potentially achieve success in real-world scenarios with government SE efforts. Moreover, we recognized that the process would likely need to be iterative, as the complexities would constantly shift. As one problem is solved, it is reasonable to believe that another might be spawned or grow in importance as a result of the interplay of the POET factors. Over time, however, the relative health of the POET environment might improve with respect to the current churn that is experienced as program stakeholders converge at major decision milestones or events and then drift apart over time (Figure 2 - Value of Iterative Approach).

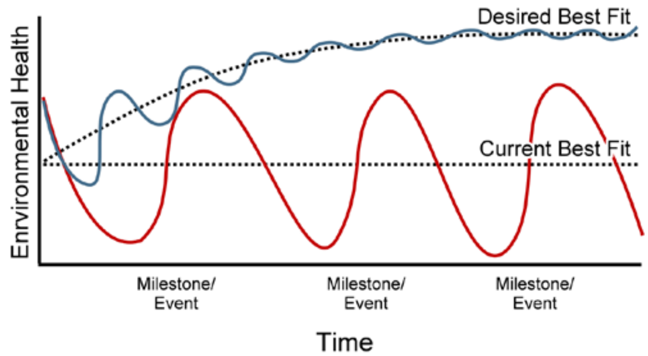

Figure 2 - Value of Iterative Approach

We identified Boyd's OODA Loop as an underlying model for our iterative approach as it has proven value in dynamic situations, and it generally models the core processes involved in learning and making decisions.[19][20] Briefly, Boyd stated that in an adversarial engagement, a person observes the environment, builds a mental model (i.e., orient) as a basis for a decision and then takes action. Although systems engineering efforts aren't overtly adversarial, we believe that the OODA Loop is a good fit because of the aforementioned need to constantly sense and understand the environment and take action in complex situations.

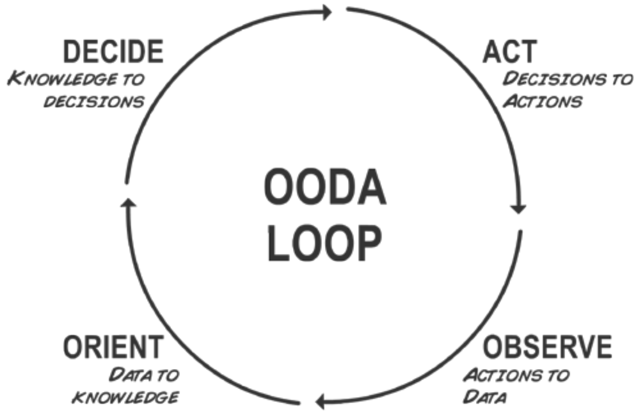

Figure 3 - Boyd's OODA Loop

From the base OODA Loop we built a cyclic flow of specific operations that a program can engage in to sense, understand and deal with POET issues. In our model, we altered the OODA Loop to better reflect the nature of systems engineering. Specifically, rather than observe, orient, decide and act, we refer to *assess, understand, plan* and *execute*. We focused on the understand and plan phases of the cycle as being the two that are directly influenced by the POET process. We broke them down into *diagnostics*, *analysis*, *pattern matching,* and *action planning* (Figure 5 - POET Process).

1) Diagnostics

In response to the absolute need for understanding among the stakeholders, our POET cycle is designed to first identify both the presence and lack of a shared awareness of problems in the diagnostic phase and then forge a higher level of understanding and possibly even consensus. In our research we have attempted diagnosis through questionnaires, interviews and observation. Initially, we had a nine-item questionnaire (Appendix A) that was intended to spark discussion during interviews. The questionnaire is now fifty-four Likert-scale questions, although the intention is to simplify and shorten the instrument as its primary value is in triggering the thoughts of the respondents for the identification of potential points of agreement and disagreement among the stakeholders.

2) Analysis

Through analysis of the questionnaire, our goal is to find problem areas, or areas of discord associated with the nine focus areas, and to make this explicit to the leadership so that they can then decide where they would like to take action. This analysis of the POET survey instrument is focused primarily on:

- Determining those areas *of disagreement* where there is lack of consensus as to the state of the program (Figure 4 - Evidence of Concern and Disagreement)
- Determining those areas of *concern* where there is consensus on problem areas
- Identifying natural clusters of respondents that answer similarly
- Identify outliers (“Grumps” and “Pollyannas”)
- Examine the relationship between the natural clusters and organizational groupings

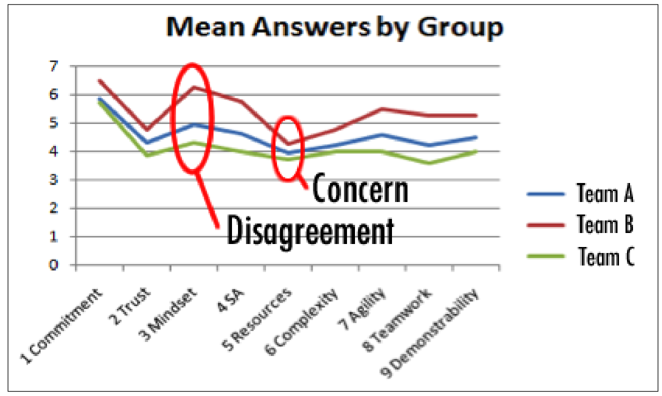

Figure 4 - Evidence of Concern and Disagreement

One approach we are using is a qualitative analysis of the interviews and written comments of the respondents. We think, however, that this type of analysis is difficult, time consuming, and not easily replicated. Our intent is to deemphasize qualitative analysis as we gain greater understanding of how to elicit such information through other means.

Another, more repeatable, analysis approach that has provided unique insights is the non-parametric statistical analysis of clusters of sentiment around different questions. As stated above, we are quite interested in points where people share concern and those where there is disagreement. By clustering the respondents we have been able to identify the natural affinity groups among stakeholders and identify the outliers. This tends to greatly simplify the problem space and help us to zero on a small number of critical POET issues that are candidates for intervention.

3) Pattern Matching

One of the more difficult tasks we’ve faced, in terms of creating a repeatable process, is moving the stakeholders from the analysis of their environment to a more developed understanding of the POET issues that they are experiencing. We settled on an approach in which we would encode our model and findings into a framework based on a *design pattern* methodology originally developed in urban planning and since widely used in systems development.[21][22] We accomplish this in two steps. The first is to match the analysis findings to a set of known *diagnosis patterns*. In our research we have found a set of recurring patterns of behavior have created a set of matching diagnosis patterns (e.g., Lack of Sponsor Commitment). These are then mapped to another set of *intervention patterns* that lay out best practices for particular situations (e.g., Leveraging Leadership).

We believe that this pattern matching approach will provide us with a strong, yet flexible approach for helping stakeholder groups to understand what they might actually *do* to overcome their POET issues.

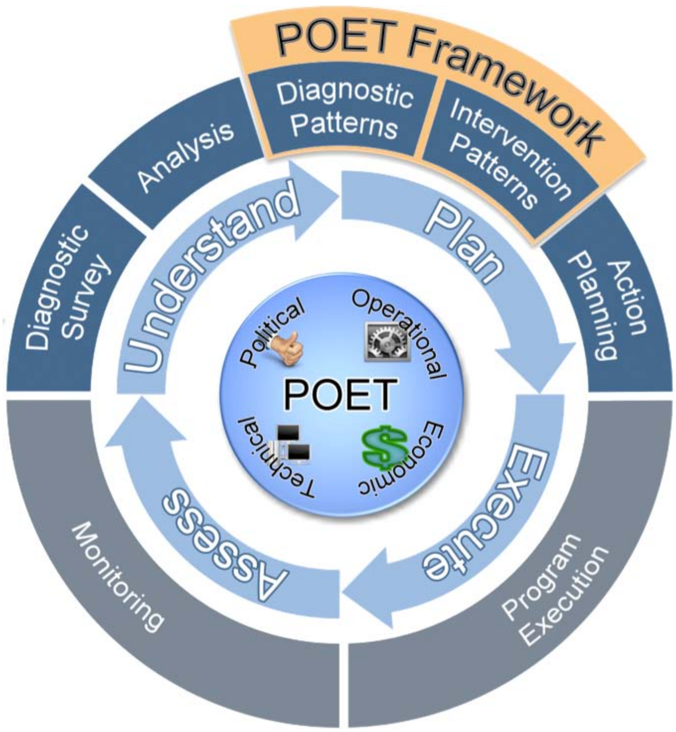

Figure 5 - POET Process

4) Action Planning

After identifying potential best practices for their given situation in the pattern matching phase, we lead stakeholders in a brainstorming exercise to gather further ideas and tailor the best practices to their particular environment. By doing so, we hope to tap into ideas that have either not surfaced or that are not widely known, as it is reasonable to expect that those with early awareness might also have developed ideas about solving a problem. Next, the stakeholders vote on their preferred interventions and these are presented back to program management, who can either take one of the favored interventions or pick another course of action.

The next stage in the process is to allow the stakeholders to make comments on the selected intervention(s) in a SWOT (*strengths*, *weaknesses*, *opportunities* and *threats*) analysis. By allowing stakeholders to comment on the interventions, they can express concerns and further increase shared understanding. Beyond the gains in shared understanding, these types of collaborative discussions also tend to help forge agreement in solutions and commitment to the selected way forward. Finally, with the SWOT comments in mind, the stakeholders complete an action plan template with roles, actions and deadlines explicitly identified. From there, we would hope that they begin to see improvements that play out in execution and assessment.

C. Field Study

We have completed a limited pilot and are currently in the midst of a larger pilot, both with DoD sponsors. A third, non-DoD, project is now being formulated.

In the first field study, according to our sponsors, we were able to accurately identify key POET issues through our diagnostic approach. This led the program management to take steps to address the associated issues.

The second pilot is in the midst of an expanded analysis phase. The initial analysis steered program management into asking more questions and asking for a second look at the data to delve into specific issues. Program management intends to continue with the pilot study.

The pilot studies have been invaluable in both refining the POET Framework, as embodied in the patterns, and our engagement approach. On the whole we have found that although stakeholders can see the value of POET, they also have to continue with their current processes and measures of success. As such, we are working to make the POET process lighter and faster so that its value is evident and barriers to use are minimized.

IV. Conclusion

By continually sharing information and ideas, and assessing stakeholder opinions of POET aspects of the program, we believe we can surface potential problems more quickly and create group solutions that will improve stakeholder buy-in. This focus on collaboration has long been a goal of the commercial world and should be fully adopted in government SE efforts.[23]

Furthermore, we believe that we can foster teamwork and commitment to program success by regularly including a wider variety of stakeholders (e.g., end users) in the ongoing SE process. The hallmarks of this effort are:

- Continual stakeholder involvement (especially end user)
- Surface perceived problems early
- Shared information and ideas to promote shared understanding
- Rapidly reach "good enough" solutions, not unanimity
- Distributed and asynchronous collaborative participation

In essence, the findings of this research effort are that the systems engineering landscape has grown more complex and unpredictable since the legacy group of serial SE approaches were developed decades ago. In response, our processes need to become better and faster at sensing, understanding and responding to the ever-changing user environment. In one word, this is agility.

Once this work is completed, we believe that the instantiated POET framework can provide the beginnings for a transformed SE process within an agile execution strategy. This may afford an opportunity to significantly influence the success of SE and acquisition efforts. We would expect that beyond increased end user satisfaction, we might see greater effectiveness and efficiency as we better account for stakeholder motivations and integrate win-win outcomes into plans. Additionally, we believe that programs will be more agile and better positioned to identify potential problem areas before they become too expensive to fix.

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VI. APPENDIX A

NINE-ITEM POET QUESTIONNAIRE

Question	Highly Disagree			Neutral		Highly Agree		
1. Stakeholders are committed to this project's success.	1	2	3	4	5	6	7	n/a
2. There is an appropriate level of trust between the stakeholders on this project.	1	2	3	4	5	6	7	n/a
3. The people working on this project put the project's overall value to the users first.	1	2	3	4	5	6	7	n/a
4. Stakeholders are aware of what is going on with the project.	1	2	3	4	5	6	7	n/a
5. This project has the appropriate resources to reach a successful conclusion.	1	2	3	4	5	6	7	n/a
6. This project has an effective mechanism for managing requirements from multiple stakeholders.	1	2	3	4	5	6	7	n/a
7. This project is adapting appropriately to changes in the environment.	1	2	3	4	5	6	7	n/a
8. Project solutions balance the views of the stakeholders.	1	2	3	4	5	6	7	n/a
9. The value of this program is understood by people outside of the project team.	1	2	3	4	5	6	7	n/a