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The influence of organization alignment on the effectiveness of systems engineers

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Abstract

Helix is a multi-year project that aims to clarify what makes systems engineers and systems engineering organizations effective. Initially, the research focused primarily on understanding the characteristics of individual systems engineers and how those characteristics relate to effectiveness. The study indicated that multiple factors influence the performance of systems engineers, a critical one being the organization where they perform their systems engineering activities [12]. There are limited studies that explore the influence of organizational culture, governance, structure, and workforce composition on systems engineering workforce effectiveness [29]. Consequently, the Helix project aims to investigate the connection between attributes of the work environment and the effectiveness of the systems engineering workforce through the implementation of both qualitative and qualitative research approaches. With insights into effective systems engineers clearly defined, the research now focuses on exploring the characteristics of organizations that impact the effectiveness of systems engineers and how these characteristics lead to an effective organizational systems engineering capability. This article presents preliminary results on the development of a web-based collection mechanism that incorporates two organization assessment methods, the Competing Values Framework (CVF) and the Quality of Interaction Index (Qi Index) that could support the understanding of the role of culture and cultural alignment in organizations implementing systems engineering.

Keywords: Systems Engineering, Organizations, Workforce, Systems Engineering Capability

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1. Introduction

The United States Department of Defense (DoD) and the Defense Industrial Base (DIB), commercial organizations that develop systems for the DoD, have been facing major challenges when developing tailored systems. Delayed schedules, cost overruns, rapid evolving mission requirements, and increased system complexity are only few examples of the complex scenarios that government agencies and their contractors face when building such systems [5],[6],[7],[8],[9]. To add another layer of difficulty to the aforementioned challenges, thousands of systems engineers who work on the development of tailored systems are reaching the end of their careers or will be retiring in the near future [3]. Consequently, organizations are offering continuous training and education in systems engineering in order to mitigate the impact of losing a significant percentage of their workforce. Nevertheless, it is unclear how effective those strategies are since there is not a standard understanding of what competencies or proficiencies are critical in systems engineering. A few of those existing strategies include, the NASA SE Competency model [21], the INCOSE UK Competency Framework [14], the MITRE Systems Engineering Competency model [18], and the Atlas proficiency model introduced by the Helix project.

In response, the Helix project started in 2012 with the objective of exploring what makes systems engineers effective and why [22],[23],[24],[12],[13). From 2012 to 2018, the Helix team interviewed 363 systems engineers and peers of systems engineers from 23 organizations of multiple domains. This portion of the research culminated with the publication of "*Atlas 1.1*: An Update to the Theory of Effective Systems Engineers" [12]. Figure 1 illustrates an overview of *Atlas*. The research team let patterns emerge in the types of roles systems engineering conducted, a systems engineering proficiency model was created, the forces that enable systems engineers to grow were identified, and lastly personal and organizational characteristics that impact systems engineer's effectiveness were recognized [13].

As shown in Figure 1, and described in *Atlas 1.1*, the characteristics of the organization where a systems engineer performs her activities have significant influence on her effectiveness. The Helix team is now exploring the influence of organizational culture, governance, structure, and workforce composition on systems engineering workforce effectiveness.

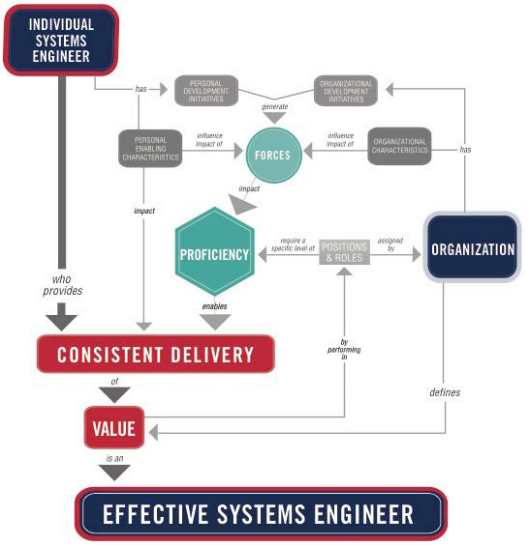

Figure 1. Overview of Atlas 1.1

The remainder of this paper is organized as follows: Section 2 provides a description of the Competing Values Framework and the Qi Index, two well-defined frameworks used in this research to investigate organizational characteristics. Section 3 describes how combining these two frameworks may show how organization culture and

the way teams work together affect organizational systems engineering capabilities. Section 4 discusses expected results from the current research, and lastly, Section 5 presents the conclusions and future research.

2. Critical Existing Frameworks

2.1. Competing Values Framework

The Competing Values Framework (CVF), as measured by the "Organizational Culture Assessment Instrument" (OCAI) developed by Kim S. Cameron and Robert E. Quinn [1], has been used by hundreds of organizations over twenty-five years to understand and describe key cultural attributes that relate to organization success. The Framework is derived theoretically and empirically from dimensions espoused by multiple scholars on organization culture, including Schein [27],[28], Kotter and Heskett [16], Ernst [4], Gordon [10], Hofstede [11], Kets de Vries and Miller [15], Martin [17], and Campbell, Bownas, Peterson, and Dunnette [2]. Figure 2 shows the key dimensions of the CVF.

In Figure 2, the upper quadrants of the figure containing the Clan and Adhocracy cultures have more of an informal environment, which supports creativity and collaboration. Whereas, the lower quadrants, Hierarchy and Market cultures, have more of a formal environment which is necessary for process-driven services and product manufacturing companies. The left quadrants in Figure 2 with the Clan and Hierarchy cultures focus on improving the internal processes for better collaboration and coordination as they have less market volatility. Lastly, the right quadrants containing the Adhocracy and Market cultures focus more on innovation and marketing efforts to compete with external competition and volatile market.

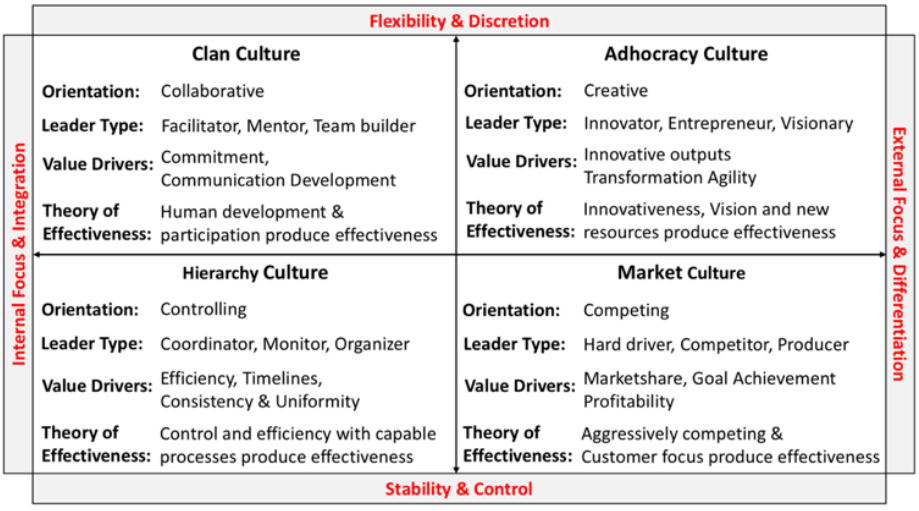

Figure 2. Competing Values Framework adapted from Cameron and Quinn (2011).

The CVF and assessment identify organizations as having one of four cultural types: Clan, Adhocracy, Market, and Hierarchy. There is no "good" or "bad" organizational culture – each type of culture can be optimal for certain types of work done in an organization. For example, Zappos, an online shoe-shopping firm is a well-known company that focuses on having the Clan culture to bring out the best services and brand name [19]. In other instances, start-up companies such as IDEO, a global design and innovation company has the Adhocracy culture to achieve success in a fast-paced and changing market [20]. Technology-focused companies such as Apple and Samsung are examples of the Market culture, focusing mainly on gaining maximum profit from sales and inventing new technologies prior to their competitors. Hierarchy culture is mainly followed by large companies like IBM and

U.S. federal government agencies with a traditional approach and structured hierarchical workforce following a strict chain of command and adhering to clearly defined processes, policies, and procedures [1].

The Helix team will use the CVF to see the impact of operating with a specific type of culture and how that culture impacts the organization's ability to deliver systems engineering capabilities. These culture types are measured by a six-item survey (the Organizational Culture Assessment Instrument (OCAI)); members of the culture divide 100 points among four alternative statements for each of six items, indicating the extent to which each alternative is similar to their organization [1]. An example is provided below. The six items include dominant characteristics, leadership, management of employees, organization "glue," strategic emphasis and criteria of success.

Table 1. Example of the OCAI current profile for dominant characteristics ([1], pp. 30)

Dominant Characteristics	**Now**	**Future**
A. The organization is a very personal place. It is like an extended family. People seem to share a lot of themselves.		
B. The organization is a very dynamic and entrepreneurial place. People are willing to stick their necks out and take risks.		
C. The organization is very results oriented. A major concern is with getting the job done. People are very competitive and achievement oriented.		
D. The organization is a very controlled and structured place. Formal procedures generally govern what people do.		
TOTAL		

Once participants assess how the culture operates "now," they repeat the process to indicate which characteristics will ensure high performance in "future." This provides a metric for the current perceived "fit" of the characteristics to the emerging needs of the organization. Since the CVF is fundamentally a tool for organizational awareness and change, the perceived fit between current and future culture attributes provides data an organization can use to plan future changes. Specifically, the CVF can be used to identify key approaches to organizational design, life cycle development stages, organizational quality, theories of effectiveness, leadership roles, and management skills ([1], pp. 35). According to Cameron and Quinn, understanding organizational culture is vital and considered as the single largest factor inhibiting organizational improvement and change.

2.2. Quality of Interaction (Qi Index)

The Quality of Interaction Index (Qi Index), introduced by Reynolds and Lewis [25], is a culture assessment method that focuses on organization behaviors, emotions, and cultural traits that are associated with the ability to adapt and innovate. The method was developed with a norm database of over 100 organizations across twenty-five industries and 20 countries. Key factors measured include cognitive diversity and psychological safety, which are shown to relate to organization adaptability and innovation. The instrument consists of 18 statements rated for the extent to which they describe the organization, and three questions where participants choose descriptive words about 1) how they feel about the organization, 2) the behaviors they see in their organization, and 3) the current state of the organization. The goal of the assessment is to identify which behaviors support an organization's generative capabilities in terms of ideas, processes and learning, and which behaviors undermine or block innovation. For instance, organizations use the Qi Index to enhance their strategy planning and execution and to develop teams and leaders. The best problem-solving teams are psychologically safe and cognitively diverse; i.e. their behavior is generative [26]. Behaviors such as experimental, encouraging, nurturing, inquiring, and curious are classified as "generative". On the contrary, behaviors such as resistant, hierarchical, conforming, and cautious come under the

non-generative category. The results of Qi Index give teams and organizations ideas for how to shift the culture, if desired [25],[26].

Helix incorporates this assessment method to facilitate the understanding of the systems engineering culture within the organization. The results of the Qi Index will describe the predominant workforce behaviors in the organization and the level of agreement or alignment among organization members. These data can be used by the organizations to better understand how they operate and to see areas for future development.

3. Methodology

The discipline of systems engineering is employed in the development of highly complex systems, often in multi-faceted, complex organizations. Initially, the Helix team interviewed 363 systems engineers from 23 organizations, focusing efforts on understanding patterns and behaviors across practicing systems engineers. One conclusion of this work was the critical influence of the organization on the effectiveness of systems engineers [12]. To better comprehend how different organizations impact the performance of the systems engineering workforce, it is necessary to investigate them in terms of culture, governance, structure, and workforce composition. This study takes a systems perspective to explore how combining the perceptions of multiple stakeholders within an organization can assist in the understanding and development of an effective systems engineering workforce. The CVF and Qi Index, described above, provide critical insights into these aspects of an organization. Paired with focused questions on systems engineers and systems engineering – which align with the previous research – the Helix team launched a survey that will allow the identification of relationships between organizational culture, teaming, and systems engineering capability. The team has not been able to identify any resources that link both the CVF and Qi Index together, let alone any that link these together with systems engineering capability.

Figure 3 presents the approach taken to investigate how multiple assessment methods can be integrated to understand organizational behaviors, specifically organizations implementing systems engineering principles.

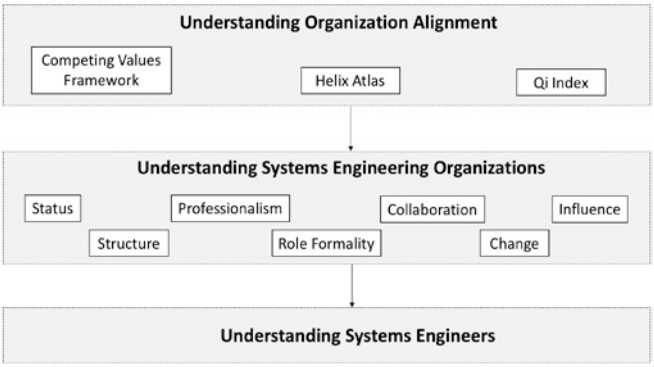

Figure 3. Helix process to investigate the how organizational assessment methods can support the effectiveness of systems engineers.

To collect organization-level data, the Helix team developed two web-based surveys that facilitate data capture and analysis. One survey focuses on systems engineers; the other focuses on their peers, managers, and leaders. Figure 4 presents a description of the data collection method, which consists of eight clustered layers as follows:

- Competing Values Framework (CVF) – As previously described, this layer describes the type of organizational culture the participant faces in his daily activities.
- Organizational Culture – The culture layer explicitly explores the status, connection level and role clarity of systems engineers.
- Governance – Organizational governance refers to the type and influence level of the decisions taken by

systems engineers and how the systems engineering processes in an organization are supposed to work versus how they operate in practice.

- Structure, Methods and Tools – This layer refers to the systems engineering approaches, processes, tools, and skills that the participant is exposed to in the organization.
- Effectiveness/Value – This layer refers to the level of effectiveness in systems engineering, the level of participant performance, and the contributions provided to the organization.
- Quality of Interaction (Qi Index) – As previously described, this layer captures specific team behaviors that impact team performance.
- Demographics – This layer captures demographic descriptions of the participants such as experience, education, role, and team participation.
- Organization Net Promoter Score – This workplace desirability score shows how strongly systems engineering and non-systems engineering members of the organization recommend the workplace for their systems engineer friends or relatives.

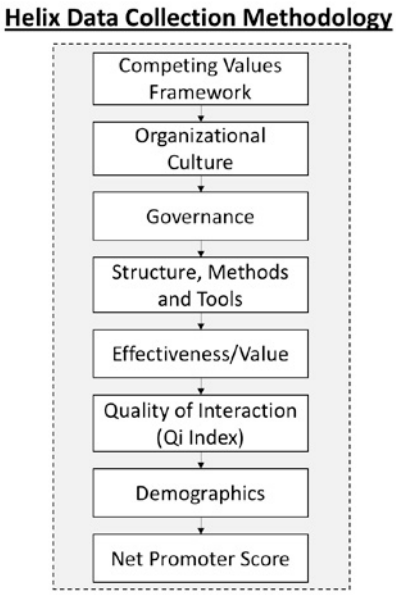

Figure 4. Topics covered in Helix web-based data collection instrument

4. Preliminary Results

In August 2018, the Helix team conducted a pilot of the first web-based survey: a proof-of-concept released to a selected group of subject-matter experts whose feedback has significantly improved the tool. The survey was finalized based on this feedback and the companion survey was created. The two surveys address the same eight elements as defined in Section III, but from different perspectives. For example, the survey for systems engineers asks the most important artifacts they deliver; the companion survey asks peers, managers, and leaders to identify the most important artifacts that they count on systems engineers to deliver. Both surveys use identical questions for the CVF, the Qi Index, and systems engineering effectiveness. When the two datasets are compared within a single organization, this provides the opportunity to validate or contrast the systems engineers' views and provides a richer, more holistic perspective on the organization.

Both surveys went through the Stevens Institutional Review Board (IRB) and upon approval were released in October 2018. To date, 42 responses have been received, though the survey will remain open through May 2019. The remainder of this section represents some preliminary results of this survey.

Of the 42 responses received 22 were from systems engineers while 20 were from the companion survey. Though at large participation in the survey is allowed and encouraged, to date all of the survey respondents are associated

with organizations in which the Helix team has been engaged in some way, such as conducting interviews or helping an organization examine their systems engineering workforce using *Atlas*. Most of these individuals also participated in interviews, which will allow the team to compare the qualitative interview data with the survey data.

The 42 responses came from 7 organizations: 2 in the US and 5 in the Netherlands. The data sets in the US organizations are currently too small to report meaningful findings. However, analysis of the Netherlands data.

4.1. Competing Values Framework

During site visits in the Netherlands, the Helix team heard repeatedly that the national culture tended to be one of collaboration and openness and that innovation was valued. The team hypothesized, therefore, that most of the organizations would score highly on the "Clan" and "Adhocracy" aspects of the CVF. Interestingly, this was only true in some organizations. Figure 5 provides an overview of the organizational profiles for five organizations in the Netherlands, called A-E here to protect organizational identities. Note that in Figure 5, the cultural attributes are shown as follows:

- Clan (A) – upper left quadrant
- Adhocracy (B) – upper right quadrant
- Market (C) – lower right quadrant
- Hierarchy (D) – lower left quadrant.

The systems engineers' responses are shown in blue and the results from the companion survey (peers, managers, and leadership) are shown in red. The solid lines represent the respondents' view on the current culture; the dotted lines represent their desires for future culture. The first item to note is that though these organizations exist within a strong national culture and are all engineering-focused organizations, their cultural profiles still vary greatly. The second is that not all organizations show a consistent view of culture between systems engineers and their peers – these distinctions provide insight on some of the other survey responses, such as whether the organization is structured in a way that supports systems engineering. While most of the respondents across organizations indicated a desired to see movement towards stronger Adhocracy culture (supporting innovation) and toward Clan culture (seeing the organization as "family"), these characteristics did not stand out as strongly as expected. Indeed in organizations B, C, and D the Market culture was seen as predominant, with systems engineers and peers alike indicating that they believe their organizations need to focus on other cultural attributes to be successful in future, including in two organizations an increase in hierarchy. This contrasts with the Helix interview data in the US, where strict hierarchy is often discussed as a detriment to systems engineering.

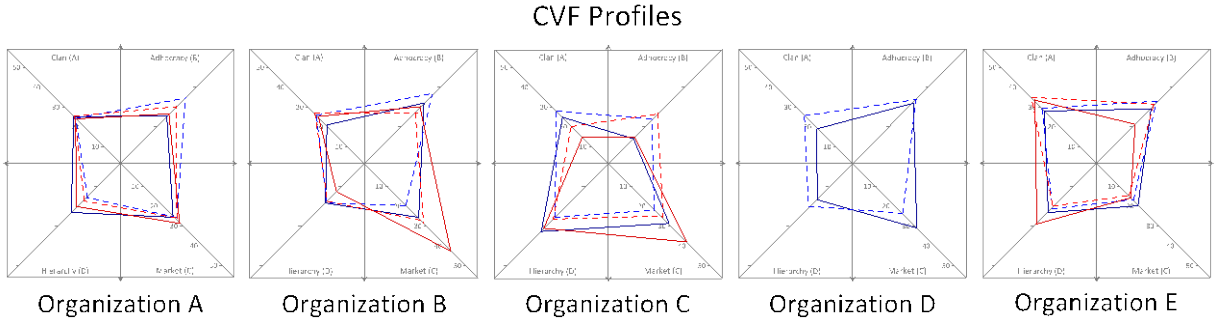

Figure 5. Competing Values Framework Profiles for 5 Organizations in the Netherlands

4.2. Quality of Interaction (Qi Index)

The Qi Index identifies "generative" and "non-generative" behaviors. Generative behaviors foster people and ideas and help create organizations that are innovative, agile and responsive. The Helix team has partnered with Human Insight to analyze the Qi Index data not just within the Helix dataset but to gain insights with the global dataset related to Qi Index.

The Qi Index examines behaviors on two axes: cognitive diversity – innate differences in how people process and experience the world around them – and psychological safety - the ability to express thoughts and feelings without fear of social sanction. A generative culture is high in both cognitive diversity and psychological safety. At the time of publication, the Helix team has final results on the Qi Index for two organizations: A and C. Organization A was, on average, seen as a generative culture, with only a few individual responses falling in the lower mid-range for cognitive diversity or psychological safety (but not both). In organization C, the cultural view was less consistent, with 63% of respondents falling below mid-range for cognitive diversity or psychological safety and one respondent rating the organization below the mid-range for both. This organization was seen on the boundary of true "generative" culture.

Data from the remaining organizations is currently under analysis and additional details will be provided as part of the conference presentation.

4.3. Comparting CVF and Qi Index

The Helix team hopes to identify the relationships between different types of cultural profiles; this is the rationale for including both the CVF and the Qi Index in the dataset. The team provides Organization A as an example below; additional insights will be provided during the conference presentation.

Organization A's CVF profile is shown in Figure 6. The results show a relatively close balance between the four aspects of organizational culture. In fact, in the data to date, Organization A shows the closest alignment between these four attributes. It is also useful to note that between systems engineers and their peers, there is close alignment. This indicates that there is a consistent organizational culture experienced by individuals in different organizational elements or functional areas. And, the desired future state (dotted lines) again aligns between the two groups: both groups show a desired decrease in Hierarchy and increase in Adhocracy, though to slightly different degrees. Again, this indicates that there is a consistent understanding of the organizational challenges and how these challenges may be addressed in future.

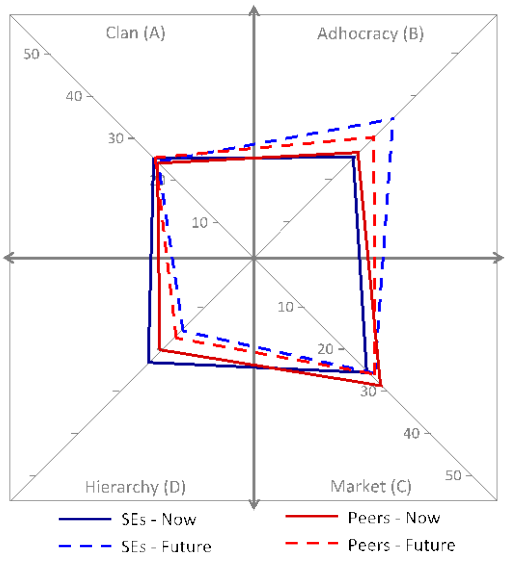

Figure 6. Organization A's Cultural Profile Using CVF

The Qi Index assessment for Organization A shows that employees see the culture as mostly generative – allowing for diversity of opinion and experiences while creating an environment in which those differences can be expressed without repercussions. A few data points placed Organization A slightly outside the generative culture. Interestingly, for the individuals whose responses did not report a generative culture, systems engineers consistently saw the challenges as related to complacency and "group think" while their peers, managers, and leaders consistently saw the challenges as more related to the inability to build off of and combine diverse ideas and move innovative solutions forward.

Both groups indicated in their CVF responses a desire to decrease Hierarchy – decreasing the emphasis on uniformity – and increase Adhocracy – increasing the emphasis on flexibility and innovation. This also aligns with the Qi Index responses which indicate that innovation is fostered and valued and uniformity is one of the challenges that impacts the ability to drive innovative solutions.

4.4. Systems Engineering Effectiveness

In the context of Helix, the organizational culture is important because it has an impact on systems engineering effectiveness in the organization. In organization A, individuals described the systems engineering process used as the "classic waterfall". In the survey, respondents were asked, "How effective is systems engineering in your organization?" on a scale of 1-5, 1 being "Very Ineffective" and 5 being "Very Effective". Two-thirds of individuals stated that systems engineering in the organization is effective (4 out of 5) and one third reporting that systems engineering is neutral (3 out of 5). No respondents reported systems engineering in Organization A as ineffective or as "very effective".

When asked their response to the statement, "Systems engineers in Organization A have the right skills to be effective", two-thirds reported that they agreed, 13% stated that they strongly agreed, and the remainder of respondents reported being "neutral". Interestingly, individuals who reported being "neutral" about this statement unanimously cited Organization A as effective at systems engineering. This indicates that while there is likely relationship between the skills of the systems engineers, there are other factors that influence systems engineering capabilities in the organization. The cultural analysis could give some insight – for example, both groups indicated a need to move toward a more innovative and flexible culture. It is possible that these changes address some aspects of culture that are currently impediments to systems engineering. Before this conclusion can be made, however, other variables have to be considered.

Respondents were asked whether systems engineers had the appropriate tools required to perform their work. In Organization A, 13% of systems engineers strongly disagreed, 13% disagreed, and only 13% agreed. The remainder of the systems engineers reported being "neutral". Gaps in tooling cited included large datasets/structured databases to utilize this data, model-oriented tools, and tools that enabled modularity and supported potential reuse.

Similar questions were asked for the organization of system engineering (two-thirds agree the way system engineering is structured is effective, one-third are neutral); the systems engineering processes (half agreed reported the processes as effective and half as neutral); and whether there were a sufficient number of systems engineers in the organization (three-quarters reported that they agreed with the statement, one-quarter were neutral).

5. Summary and Discussion

Section III provided an overview of the types of data collected and some preliminary findings. The Helix team urges against the over interpretation of the data at this stage, as it hopes to collect at least three times as more data than is reflected here.

The overarching goal of the Helix team is to create categorizations of organizations based on the eight variables outlined in Section II and determine the relationships between those variables. In particular, what organizational profiles support specific types of systems engineering. As the research progresses, the team hopes to be able to address the following types of questions:

- How does the CVF relate to the Qi Index?
- How does organizational culture impact specific types of systems engineering (i.e. what different cultural profiles are required to support traditional systems engineering versus model-based systems engineering or rapid/agile approaches)?

- What types of organizational structures, and methods for integrating systems engineering into the organization, best support different types of systems engineering?
- What are the primary contributions the systems engineering discipline makes in an organization?
- How is effective systems engineering defined? How can this be measured?

The Helix research is ongoing and is expected to conclude in December 2019.

Acknowledgements

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