Helix: Developing an Understanding of Organizational Systems Engineering Effectiveness

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Table of Contents

List of Figures

List of Tables

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Nicole AC Hutchison

Nicole AC Hutchison
Helix Principal Investigator

There is significant interest in DoD, as well as in Congress, in ensuring that DoD can characterize and manage its SE workforce. It is also critical to have a baseline understanding of the SE workforce to determine the impact of SERC and other DoD human capital efforts to improve the workforce. This will allow the DoD to determine how the workforce can better support the acquisition of defense systems, and to identify the specific impact of efforts to improve the SE workforce, such as recruiting and retention programs. This information will also inform the SERC on how to thoughtfully adjust its own human capital research program.

This research task aims to answer one primary research question, with three sub-questions, that have not been addressed with a significant systematic effort:

Effectiveness: How can organizations improve the effectiveness of their systems engineering?

1. Why: How does the effectiveness of the systems engineering workforce impact the overall ability of an organization to successfully deploy increasingly complex systems and solutions (i.e., to have an effective systems engineering capability)?
2. What: What critical factors, in addition to individual workforce effectiveness, are required to enable systems engineering capability? Factors include tools, practices, processes, policies and culture. Engineering is a social activity, so the means of aggregating individual capabilities is critical.
3. How: How do the variables that impact systems engineering effectiveness need to shift to enable different systems engineering approaches? Given a specific situation, how can one evolve to a preferred operational outcome? This is not starting point independent?

In 2018, the Helix team engaged **seven new organizations** and a**dded over 100 new interviewees** to the dataset, bringing total participation to 464 individuals and 29 organizations, with additional consultant interviews (not specific to a given organization). With this large dataset, the qualitative analysis methods used previously are no longer adequate to keep pace. The team has stood up data mining and analysis capabilities, including natural language processing, topic modeling, and cluster analysis. These approaches highlight relationships in the data that the Helix team can then more qualitatively explore. In addition, Helix launched a survey to collect detailed data on organizational culture; systems engineering structure, governance, and methods, processes, and tools; system engineering effectiveness; and teaming. This detailed data is paired with the interview data to identify critical relationships between organizational and workforce characteristics and systems engineering effectiveness. Finally, the Helix team created web-based tools to allow individuals to self-assess based on the proficiency (knowledge, skills, abilities, behaviors, and cognitions) and career path findings of *Atlas* (Hutchison et al., 2018).

This report reflects the ongoing analysis of data collected. Data collection is slated to be completed for Helix in June 2019.

Organizations interested in participating in Helix can use the information in Appendix I or contact the Helix team at helix@stevens.edu.

1 Introduction and Purpose

The U.S. Department of Defense (DoD) has a strategic need to define what enables superior product development. The Systems Engineering Research Center (SERC) performs research and advances the state of the art in systems engineering – a critical enabler of successful development. The SERC and its sponsors have developed a research agenda around four thematic areas. One area in particular, systems engineering (SE) human capital development, is especially relevant to this research task. A goal of the SERC's human capital research strategy is to reduce the professional development time of highly capable systems engineers and technical leaders, both within DoD and in the defense industrial base and to improve the effectiveness of those systems engineers and technical leaders.

There is significant interest in DoD, as well as in Congress, in ensuring that DoD can characterize and manage its SE workforce. It is also critical to have a baseline understanding of the SE workforce to determine the impact of SERC and other DoD human capital efforts to improve the workforce. Having a current understanding of the SE workforce will allow DoD to determine how the workforce can better support the acquisition of defense systems, and to identify the specific impact of efforts to improve the SE workforce, such as recruiting and retention programs. This information will also inform the SERC on how to thoughtfully adjust its own human capital research program.

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3. How: How do the variables that impact systems engineering effectiveness need to shift to enable different systems engineering approaches? Given a specific situation, how can one evolve to a preferred operational outcome? This is not starting point independent?

This is a shift in Helix from an individually focused approach (within the SERC Human Capital Development Strategy area) to encompass how organizations can become more effective at systems engineering, including how they better enable their systems engineering workforce. In essence, this is a hybrid between the SERC Human Capital Development and Systems Engineering and Systems Management Transformation areas. Elements of Enterprise Systems of Systems are relevant here as groups within the system often have their own culture and may act semi-autonomously. The previous Helix work on individual systems engineers has been a critical input to this project.

1.1 About This Document

This document reports on the research findings from the research questions and updated Helix methodology. The major sections of this document include:

- 2: *Background*: This section provides an overview of the Helix project.
- 3: *Updated Helix Methodology*: This section provides detailed description of the methodology used in this research project. The development of the survey, web-based tool, data mining, and the diversification of the dataset are elaborated in this section.
- 4: *Results*: This section provides guidance for organizations that wish to use *Atlas* to help guide and grow their systems engineers. It includes examples from the organizations highlighted in Section 3 by name. There are additional examples organizations that have participated and provided feedback on their experiences but not spoken publicly; these are anonymous.
- 5: Conclusions: This section summarizes the research performed by the Helix team.
- 6: Future Research Directions: This section highlights the future research path, continuation, and expansion of the Helix project.

2 Background

In 2012, the SERC was tasked with investigating what makes systems engineers effective. From 2012-2018, the Helix team developed *Atlas: The Theory of Effective Systems Engineers*. Through qualitative data analysis on in-depth interviews with 464 individuals across 29 organizations, *Atlas* provides insights on what enabled systems engineers to deliver consistent values. The main model for *Atlas* appears in Figure 1 and is elaborated below.[1]

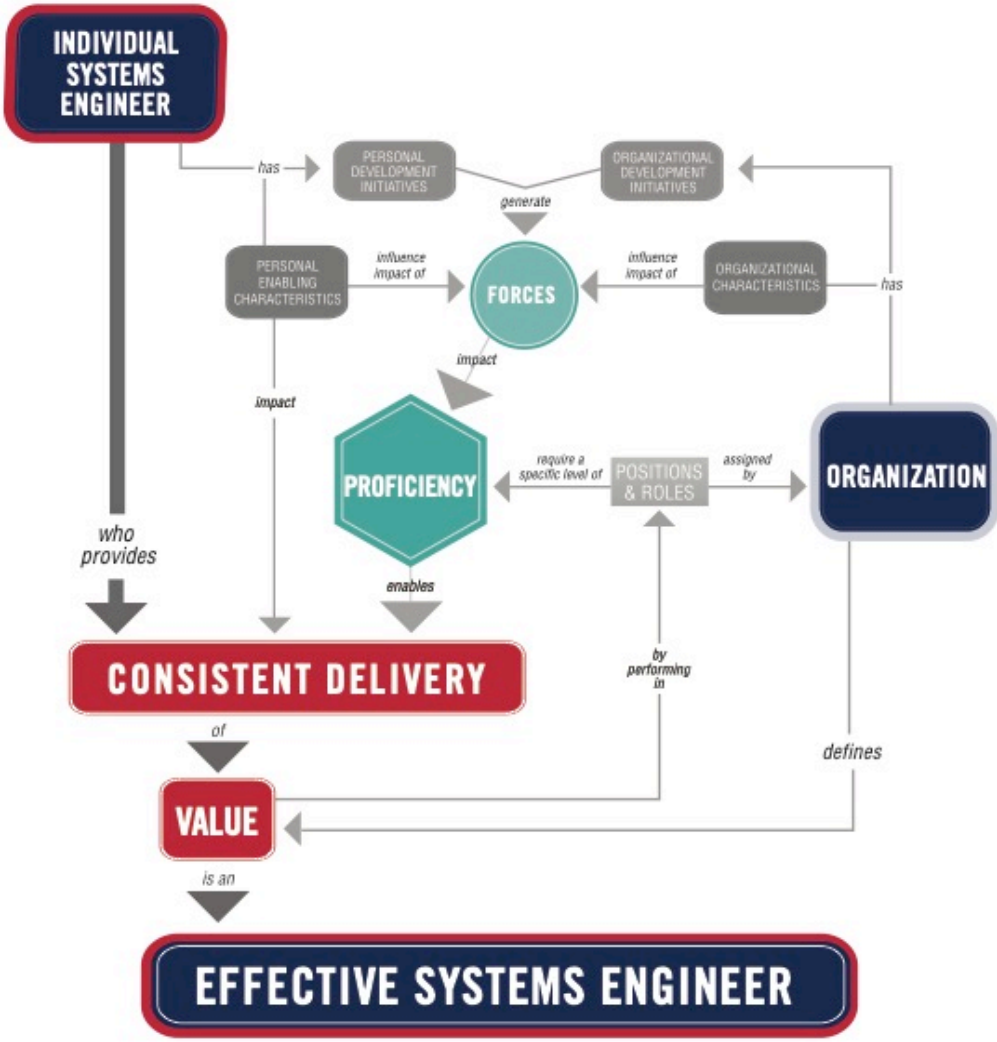

Figure 1: Relationship between Helix and *Atlas* (Hutchison et al., 2018a)

The critical values that systems engineers provide include (Hutchison et al., 2018a):

- Keeping and maintaining the system vision;
- Translating technical jargon into business or operational terms and vice versa;
- Enabling diverse teams to successfully develop systems;
- Managing emergence in both the project and the system;

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[1] The *Atlas* framework was reviewed in light of the additional data collected in 2018. Though data analysis is still ongoing, current analysis does not indicate any required changes to *Atlas.*

- Enabling good technical decisions at the system level; and
- Supporting the business case for the system.

Individuals provide these values in the context of their jobs – through the positions they fill and the roles they play. The Helix team built on previous frameworks (Sheard, 1996 and Sheard, 2000) to create a set of 15 systems engineering roles, groups related systems engineering activities. In order to perform in these roles, systems engineers have a critical set of knowledge, skills, abilities, behaviors, and cognitions – or proficiencies. *Atlas* provides a tailorable proficiency model for assessing systems engineering skillsets. There are three main forces that enable systems engineers to build these skills: experiences, mentoring, and education and training. Patterns in these forces over time provide insights in the career paths of systems engineers. (Hutchison et al., 2018b) In addition to the skillsets required for systems engineers to be effective, there were critical personal characteristics that also better enabled systems engineers to grow such as self-awareness and inquisitiveness.

All of these aspects about an individual systems engineer occur in a context of the organization in which he or she works. The organizational context is critical to the effectiveness of systems engineers. Organizations pair individuals with the roles and responsibilities identified in positions, set expectations for the proficiencies required for a given position and the values that position should provide, and help determine how to grow their systems engineering workforce. Likewise, the characteristics of organizations also impact a systems engineer's ability to be effective. Organizations that have an unclear definition of what systems engineering is, that do not value or reward systems engineering activities tend to make it more difficult for systems engineers to provide the values listed above.

At the level above, this model is fairly generic and could be tailored to any discipline – the organizational context and culture impact all employees and every discipline has a set of requisite skills and expectations about how those skills will be developed. This is intentional; as a theory, *Atlas* should have some generalizable principles. It is at the next level of detail that *Atlas* becomes very specific to systems engineering, providing values systems engineers provide, the proficiencies required for systems engineers, the roles of systems engineers, career paths for systems engineers, and characteristics of effective systems engineers. For more detail on *Atlas*, see (Hutchison et al., 2018a, Hutchison et al., 2018b, Hutchison et al., 2018c, Hutchison et al., 2016, Hutchison et al., 2017).

Evolution. With all of the insights developed around systems engineers as individuals through *Atlas*, the Helix team set out to answer a new set of research questions. The new focus become on what makes *organizations* effective – or not –at systems engineering. The primary research questions are around effectiveness:

- How can organizations improve the effectiveness of their systems engineering workforce?
- Why: How does the effectiveness of the systems engineering workforce impact the overall ability of an organization to successfully deploy increasingly complex systems and solutions (i.e., to have an effective systems engineering capability)?

- What: What critical factors, in addition to individual workforce effectiveness, are required to enable systems engineering capability? Factors include tools, practices, processes, policies and culture. Engineering is a social event, so the means of aggregating individual capabilities is critical.

- How: How do the variables that impact systems engineering effectiveness need to shift to enable different systems engineering approaches? Given a specific situation, how can one evolve to a preferred operational outcome? This is not starting point independent.

During the previous phases of this effort, the SERC has made substantial progress towards answering these four research questions. The Helix research team has produced over two dozen publications on Helix, eight technical reports, *Atlas: The Theory of Effective Systems Engineers*, an *Atlas Implementation Guide*, and an *Atlas Career Path Guidebook*. The team also formed an advisory group (the Helix Advisory Panel or HAP) and held four workshops to discuss Helix research findings and plans.

With this new focus, the Helix team has developed new approaches to enable the development of a theory of what makes systems engineering organizations effective. Section 3 provides the updated Helix methodology and efforts to expand the data collection with a focus on the culture, structure, teaming, and governance of systems engineering organizations to identify patterns that make them effective.

The Helix project began as a multi-year longitudinal study in 2012 with a primary focus on understanding what makes systems engineers effective. The research questions were combined with a ground theory approach using a mixed methods approach (Creswell and Plano, 2011). In the social sciences, grounded theory is a method for developing theory that is grounded in data collected and analyzed in a systematic manner (Goulding, 2002). The mixed methods approach refers to the qualitative and quantitative research methods. Although the initial data were collected from DoD and DIB organizations, the team expanded the data collection process by interviewing non-DoD organizations in 2015. The research resulted in *Atlas: The Theory of Effective Systems Engineers,* which is centered on the notion that individual Systems Engineer who provides consistent delivery of value is an effective systems engineer (Hutchison et al., 2016). Figure 2 shows the conceptual framework for *Atlas^{ORG},* which is the incremental update to the theory that includes the organizational study to evaluate and understand the unique organizational characteristics of systems engineering organizations based on culture, governance, and structure.

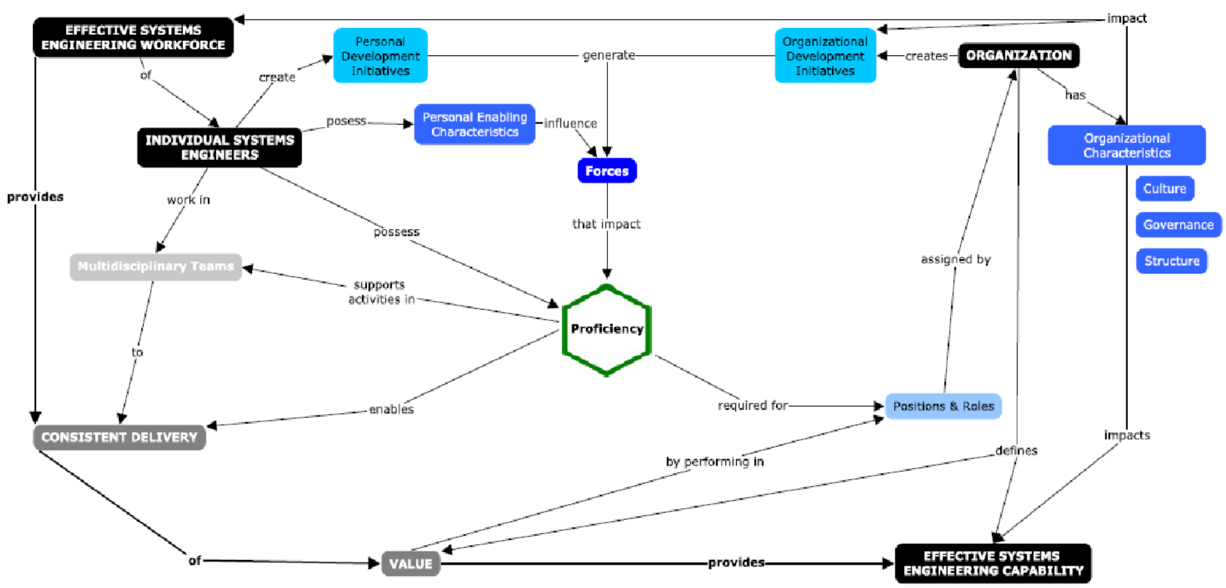

Figure 2: DRAFT *Atlas^{ORG}*: *Organizational Study*

The aggregated data sources include interviews, survey responses, the participant's resumes or curriculum vitae, and the organizational data from different artifacts from participating organizations. The participants from the interviews were individuals who are doing systems engineering work on programs, supervising systems engineers, using products from systems engineers, or are knowledgeable about the systems engineering characteristics in their organizations. Follow-up interviews were also conducted to gather additional data for clarification or filling data gaps.

The organizational data include documents related to the purpose of the organization, its business and customers, information about the workforce in general or systems engineering, the demographics of the systems engineering population, and organizational initiatives that may have an impact on systems engineers (Hutchison et al., 2014). Using qualitative analysis, the aggregated data from the interview transcripts or detailed summaries are reviewed and coded by the Helix team to find patterns of the research themes.

From June 2013, when Helix conducted its first site visit for data collection, until February 2019, a total of **464 participants** have been interviewed from **29 organizations** and a group of consultants, who have insights across a variety of organizations. Interview participants, if willing, also provided their resumes with details about their educational background, work experiences, and participated in surveys, which were launched in 2018. Follow-up interviews were conducted over the telephone with willing participants, to explore topics that could not be covered in the initial face-to-face interviews or to collect additional information based on their resumes. Follow-up interviews were also used to validate results of Helix analysis.

Figure 3 provides a breakdown of participants by domain. Nearly half of the individuals who participated in Helix currently work on defense systems, Roughly 10% of the participants work in industrial organizations that develop both defense and commercial aerospace systems; because both groups were interviewed and many individuals worked across areas, these are reported separately. The remaining participants are from across commercial aerospace, healthcare, transportation, telecommunications, or information technology, or "high tech" companies that focus on complex technological advancement.

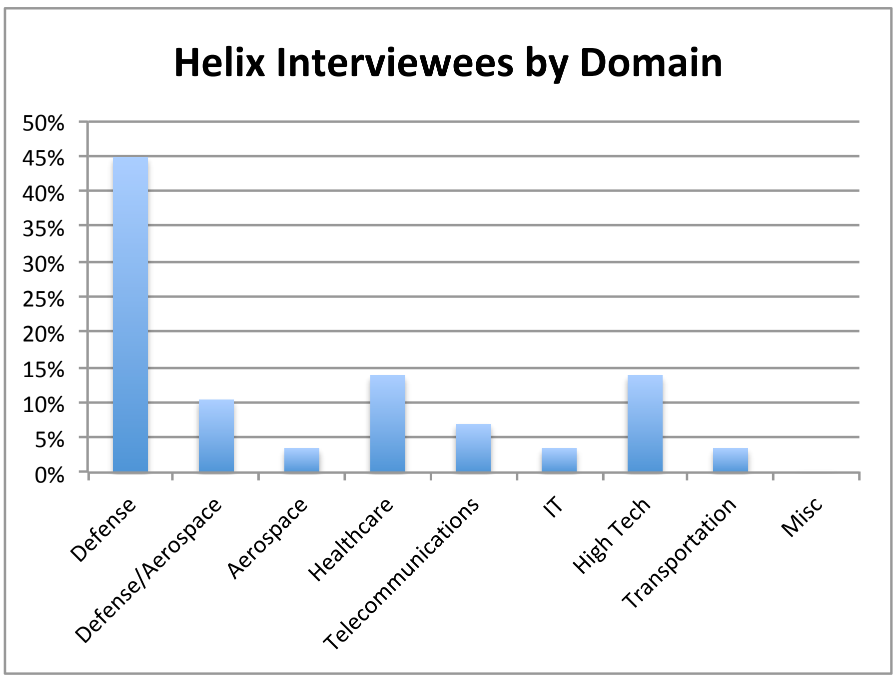

Figure 3: Distribution of Individuals by Organization

Another classification of the type of participant organizations is their commercial affiliation. Helix classified commercial affiliation into: Government, Industry and Federally Funded Research and Development Centers (FFRDC). As it can be observed in Figure 4, more than half of the participants belong to industry organizations. The rest of the dataset is distributed among government entities and FFRDC, the former covering roughly 30%, while FFRDC's make up roughly 10% of the sample.

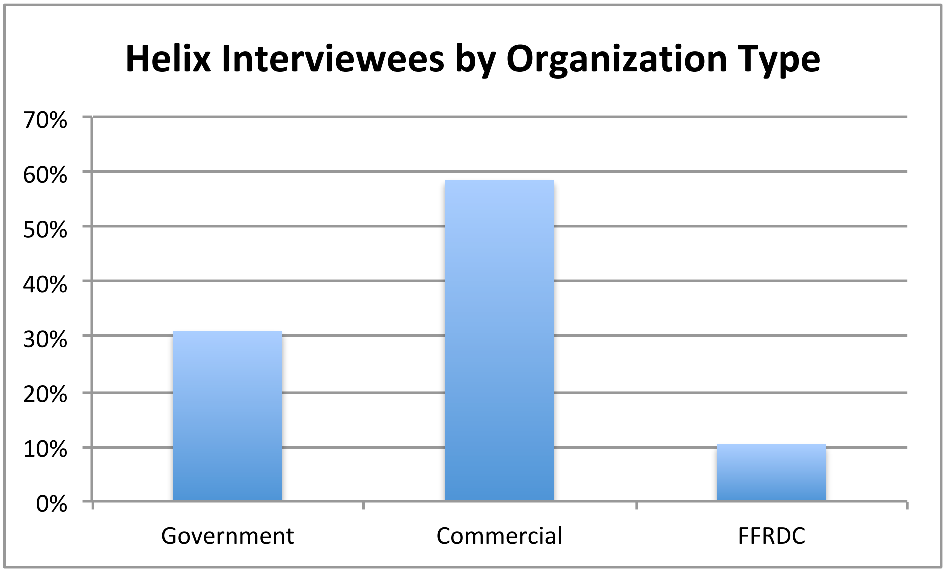

Figure 4: Individuals by Organization Type

Updated Research Methodology. The interviews conducted through 2018 have created a rich text-based dataset: over 6,500 pages of notes and transcripts that have been qualitatively analyzed to create *Atlas*. However, such a robust dataset has one major drawback: qualitative analysis methods which rely on manual coding are time consuming and combing through the dataset manually for a new type of insight can take months. The Helix team has updated the research methodology to enable different types of data collection and to utilize existing data in new ways.

The following subsections provide the description of each type of data collection and analysis approach that was introduced. The methodology for data collection, interviews, etc., as reported in (Hutchison et al., 2018) have not changed.

3.1 Updated Questions for Organization Site Visits Interviews

With the shift in focus from studying the effectiveness of individuals to organizations, the team updated the interview questions to include organizational culture, governance, and structure variables for organization site visit interviews. The organizational site visit interviews are conducted either in person or via teleconference. One to three focus groups of three to five managers or stakeholders of systems engineering work are conducted at each session using a structured interview approach. Questions explore perceptions of systems engineering status, value, clarity of roles, involvement in key decision-making, effectiveness of teaming, and contributions to the project or organization. The discussion sessions are recorded, if permitted and transcribed for later analysis. The following are the four focus group questionnaires and focus areas related to systems engineers:

- Systems engineers: Defining systems engineering in the organization and exploring organizational characteristics that support or hinder from systems engineers' effectiveness
- Executives and senior leadership: Defining systems engineering and the integration of systems engineering in the organization

- Human resources: Understanding the organizational positions on systems engineering
- Peers and practitioners in related discipline: Understanding the overlap between systems engineering and the related discipline work and organizational culture in the organization

The objectives for extending the interviews to include executives and senior leadership are to validate or modify the current Helix understanding of values provided by systems engineers and examining how systems engineering effectiveness is viewed within an organization. For the human resources interviews, the goals are to gather official organizational views on systems engineering roles, positions, career paths, and advancement, as well as to collect additional data points on organizational culture outside of the systems engineering group. The team extended the questions to peers and practitioners in related disciplines to understand the overlap in views for systems engineers and non-systems engineers who have related professions. All the discussion questions are included in Appendices C through F.

3.2 Survey

There are two versions of the web-based survey, one for participants who are currently performing systems engineering functions and one for their peers, managers, and leadership – stakeholders of their work that can provide feedback on the information collected from systems engineers. The two surveys have parallel structure, using different wording to collect the perspectives of these different groups on the same topics.

The web-based survey consists of Likert-scale and free text questions divided into four sections: demographic information about the respondent and their organization; a widely-used culture assessment tool called the “Organizational Culture Assessment Instrument” (OCAI) which maps into the Competing Values Framework (CVF) (see 3.2.1); questions specifically about systems engineering practices and effectiveness, and their relationship to culture, structure, and governance (3.2.2); and a team behavior instrument called the “Quality of Interaction Index” (Qi Index) (see 3.2.3). The CVF and Qi Index are both tools that examine specific aspects of organizational culture and are built upon broad, global datasets that can provide additional context.

The web user-interface was tested in a pilot study including current and former systems engineers (n=13) and revised based on usability feedback. Time to complete the surveys is approximately 45 minutes depending on the number and extent of fill-in questions the participant chooses to answer. When an individual from an organization that also participates in Helix interviews completes the survey, they are provided an organization code; this allows the teams to link interview and survey responses. Names of organizations and individuals are recorded initially for internal use, but then deleted from the dataset. This information is used to check that participating organizations and individuals are properly linked (i.e. if A Company participates in interviews and a respondent lists A Company as their organization, the team will match this individual’s responses to the organization for analysis and, if they participated in interviews, to their unique ID).

Surveys have limitations but are good for enabling clear and consistent data collection, though without the rich context of interviews. Survey results are generally easier to analyze and enable different types of analyses that are less time consuming than qualitative data analysis. In addition, anonymous individual surveys enable respondents to give their private views of the organization and its culture without concern for stating the "party line" in a group interview. The data from these individuals serves as a reliability check on the conclusions drawn from group interviews. Paired with the surveys, the team conducted some individual and group interviews with participating organizations to explore topics in greater depth.

3.2.1 Competing Values Framework (CVF)

The widely-used culture assessment tool called Competing Values Framework (CVF), measured by the OCAI was developed by Kim S. Cameron and Robert E. Quinn (2011). The CVF has been used by hundreds of organizations over two decades to understand and describe key cultural attributes that relate to organization success. Numerous scholars' theoretical and empirical works on organization culture, including Schein (1983; 2010), Kotter and Heskett (1992), Ernst (1985), Gordon (1985), Hofstede (1980), Kets de Vries and Miller (1986), Martin (1992), and Campbell, Bownas, Peterson, and Dunnette (1974), contributed to the framework's dimensions. Figure 5 shows the key dimensions and brief descriptions of the CVF, which include the clan, adhocracy, hierarchy, and market cultures. The four cultural types in the CVF and survey assessment are used to identify organizations based on the organization's orientation, leader type, values that drive their organizations, and the theory of effectiveness within the organizations. The culture can by optimal based on the work performed in each organization.

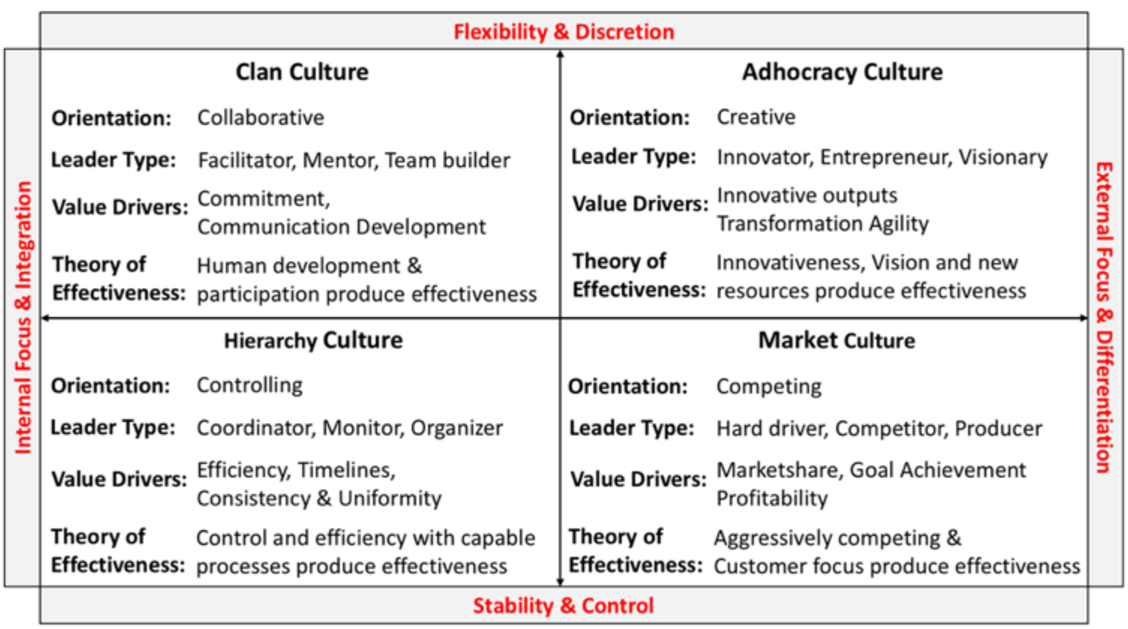

Figure 5: Competing Values Framework adapted from Cameron and Quinn (2011)

The CVF is incorporated with permission in the surveys developed by the Helix team to investigate the culture types and how it impacts the organization's ability to deliver systems engineering capabilities. These culture types are measured by a six-item survey based on the 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 like their organization (Cameron and

Quinn, 2011). The six items include dominant characteristics, leadership, management of employees, organization “glue,” strategic emphasis and criteria of success. Table 1 provides an example of the OCAI current profile for the domain characteristics.

Table 1: Example of the OCAI current profile for dominant characteristics (Cameron and Quinn, 2011, pp. 30, used with permission)

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,” the process is repeated to indicate which characteristics will ensure high performance in “future.” Given that the CVF is a tool for organizational change, the “now” and “future” culture assessments by the participants provide a metric for the current perceived “fit” of the characteristics to the emerging needs of the organization. The CVF can be used to identify approaches to organizational design, life cycle development stages, organizational quality, theories of effectiveness, leadership roles, and management skills (Cameron and Quinn, 2011, pp. 35). The culture assessment data can be used to plan future changes and increase overall cultural awareness within an organization.

The Helix team obtained permission to use the OCAI instrument in this research from Kim Cameron on June 4, 2018. The OCAI is available free of charge to research groups. If organizations choose to compare their culture data with the Cameron database of over 10,000 organizations and 100,000 individuals across five continents, they can purchase additional data collection and comparisons from BDS, Behavioral Data Services, 734-663-2990, Sherry.Slade@b-d-s.com.

3.2.2 Survey Questions Specific to Systems Engineering Capability and Effectiveness

The web-based tool includes quantitative and qualitative survey questions on how systems engineering is perceived, conducted, supported, and evaluated in an organization. These questions appear in between the two culture inventories in the survey.

This portion of the survey contains four parts:

1. Perceptions of systems engineering and systems engineers: Status, value, role clarity, influence, collaboration, and aspects of the culture that help or hinder systems engineering success

2. Perceptions of systems engineering governance: Official roles in key decisions, direct impact on success of project, executive champions of the discipline, and the connection of the systems engineering charter to the mission of the organization.

3. Perceptions of the processes, methods and tools of systems engineering: Effectiveness of organization structure, effectiveness of systems engineering approaches used, access to tools, use and non-use of leading-edge processes and tools, and the skill level of systems engineers in current roles.

4. Perceptions of systems engineering effectiveness: How effective is systems engineering, what does it mean to be effective, what the organization counts on systems engineers to deliver, and willingness to recommend a friend to work in the organization as a systems engineer.

These questions enable the team to link the data from the OCAI and Qi Index specifically to the conduct of systems engineering in an organization. And, again, this provides the opportunities for individuals who participated in interviews to provide more specifics on these areas in a more anonymized fashion.

3.2.3 Quality of Interaction Index (Qi Index)

The Qi Index is a culture assessment method that focuses on organization behaviors, emotions, and cultural traits that are associated with the ability to adapt and innovate (Reynolds and Lewis, 2017), the Qi Index was developed by Reynolds and Lewis 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 Qi Index 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 Qi Index assessment is to identify which behaviors support an organization's generative capabilities in terms of ideas, processes and learning, and which behaviors undermine or hinder 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 (Reynolds and Lewis, 2018). Some words are consistently associated with generative organizations while others are consistently associated with less generative or less innovative teams in prior research.[2] The results of the Qi Index give teams and organizations ideas for how to shift the culture, if desired. (Reynolds and Lewis, 2017; 2018).

At a House of Representatives hearing "Promoting DOD's Culture of Innovation," Dr. Michael Griffin argued that the increasingly global R&D landscape requires DOD to place a premium on

[2] The Helix team will provide more detail on the specific characteristics related to generative versus non-generative organizations in the next report. However, it is the hope of the team that organizations reading this report may be interested in participating and, therefore, the team does not wish to highlight the "right" or "wrong" answers here. The Reynolds and Lewis reference provides additional detail if desired.

the speed at which it can develop and field new capabilities.[3] The Helix team chose the Qi Index in part because it specifically incorporates assessment of teaming that fosters or inhibits innovation. This method also facilitates 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.

In addition, the Qi Index data will be integrated with OCAI culture data to test whether combining an overall culture assessment method with an interpersonal team dynamics method can provide specific suggestions for organization actions that could enhance performance. Since both instruments are publicly available, any organization in this research may choose to expand their use across their organization after receiving the Helix analysis. This gives participating organizations ownership of their own development once Helix concludes and an opportunity to re-test themselves to check progress after implementing targeted change.

Finally, the Helix team has paired with Human Insight, the organization that oversees the global dataset for the Qi Index. Human Insight runs the data collected from each organization against their global database to provide clear comparisons against other organizations in the same industry. This provides valuable insights and baselining for participating organizations and also helps to the Helix team understand whether there are critical differences between organizations that place an emphasis on systems engineering in a domain; in other words, it is an indicator of how generalizable these results may be.

3.2.4 Selection of Survey Sample

Two types of survey participants were recruited: within organizations and at-large. Surveys completed within organizations contained an organization identifier to enable organization-specific data analysis and conclusions. Surveys completed by at-large participants were grouped together to look for general patterns across the systems engineering community.

1. Within organization participants: All organizations recruited after July 2018 were given the opportunity to participate in the survey. Each organization determined who from their organization was eligible to complete the survey. Participation was voluntary. The Helix team encouraged organizations to distribute the survey link to systems engineers, their managers, peers, and other stakeholders of systems engineering work. The Helix team also distributed the survey link to everyone they interviewed and encouraged people to share the link with others to increase participation.

2. At-Large participants: Practicing systems engineers, managers, peers, and other stakeholders of systems engineering work products were recruited at systems engineering related professional, industry, and DoD conferences and workshops. Participants were also recruited through professional organization newsletters including INCOSE and SERC communications.

[3] https://www.aip.org/fyi/2018/new-dod-rd-chief-outlines-vision-jumpstarting-military-innovation

As of January 2019, the team received 47 completed surveys from six organizations. The survey sample is shown in Figure 6. Nearly two-thirds of the organizational participants are systems engineers and the remaining respondents are managers, peers or other stakeholders. Of these, 98% are from industry and 2% are from DoD organizations.

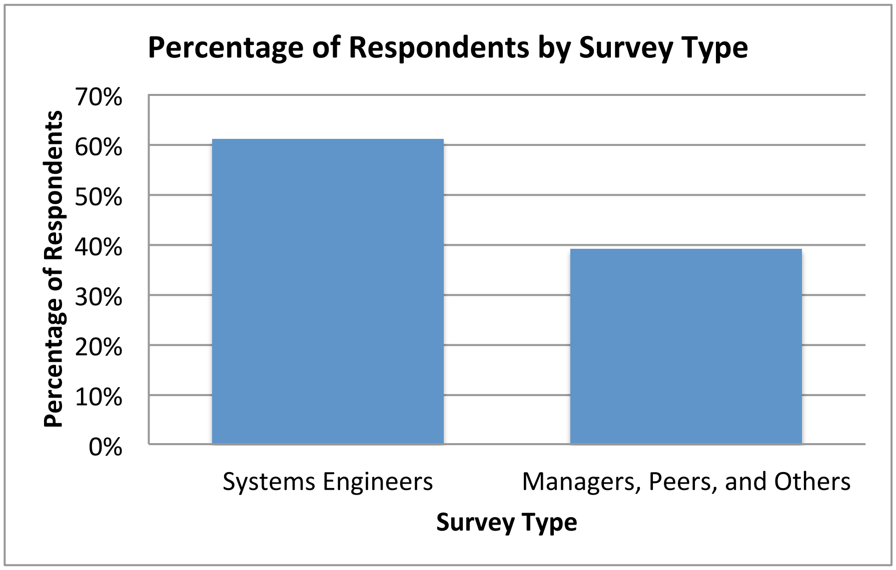

Figure 6: Survey Sample

The Helix team will continue to collect survey data through Spring 2019. A few results are highlighted in Section 4.1 and Appendices G and H provide an overview of current results, but should not be viewed as final. The final results will be reported after the data collection is completed.

3.3 Web-Based Tools

The Helix team has developed a set of web-based tools to enable individuals to assess their own proficiencies and career paths. This is based on *Atlas* 1.1 and is available to any organization or individual. This replaces the paper-based and Excel-based methods used previously. Individual systems engineers can utilize these insights to develop their own growth and development plans using insights from *Atlas*. And, if an individual agrees, the Helix team can use an anonymized version of this data for further research.

The Self-Assessment Tool is built using an advanced technology stack, which include Laravel and MySQL. Laravel is the most popular, open source PHP framework used to build Web Applications. It helps to maintain an MVC (Model - View - Controller) architectural pattern along with providing other features like Eloquent ORM, Blade templating engine, Routings, Restful Controllers, Security methods, and others. MySQL is an open-source relational database management software. Figure 7 shows the user dashboard of the self-assessment tool.

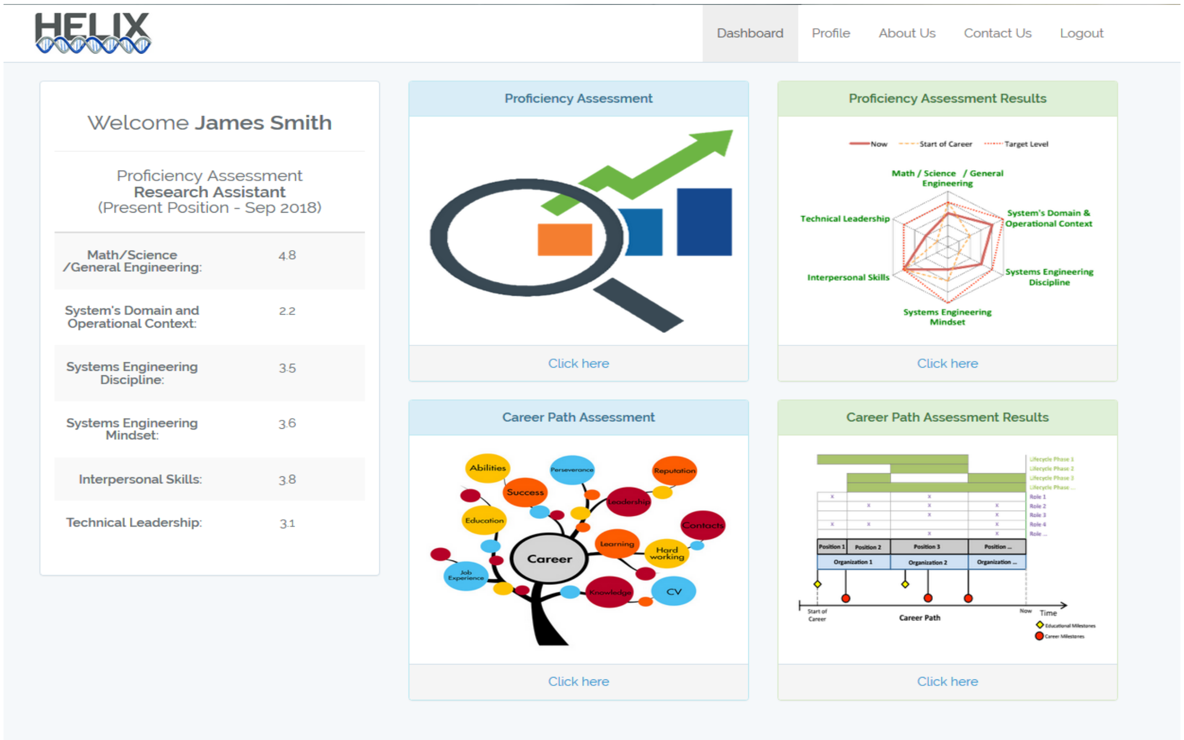

Figure 7: Self-Assessment Tool (User Dashboard)

The Self-Assessment Tool is a Single Page Web Application (SPA), which uses Bootstrap, an open source front-end framework that enhances the application by providing a clean and easy to use User Interface. Systems engineers can use this tool to assess their proficiencies and career paths efficiently and in a more visually appealing manner. The proficiency assessment represents an individual's self-assessment on his/her knowledge, skills, and abilities in past, current and future positions in six areas:

- Math/Science/General Engineering
- System's Domain and Operational Context
- Systems Engineering Discipline
- Systems Mindset
- Interpersonal Skills
- Technical Leadership

The individual will have to score himself/herself in each of the area on a scale of 0-5 for every position with 0 representing the least proficiency and 5 representing the most proficiency. The tool then uses this data to create a radar chart, which depicts the past, present, and future proficiencies of an individual. This enables the individual to keep track of his/her progress through each position. Figure 8 displays the proficiency assessment results in the form of a radar chart to provide a holistic view of the individual's proficiencies.

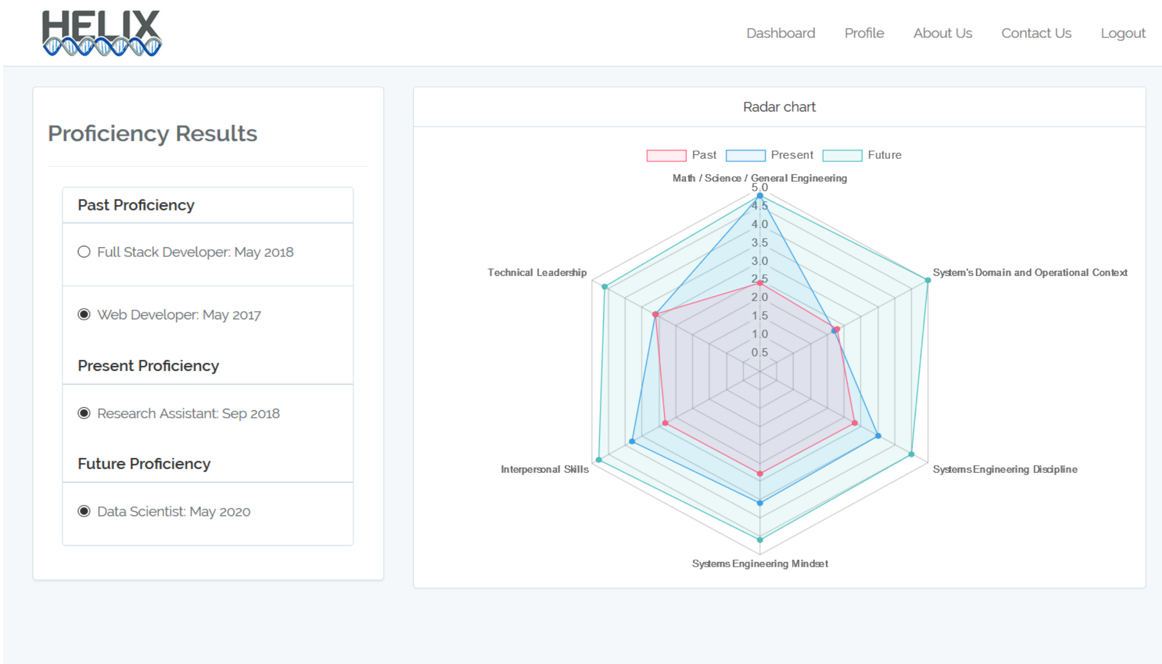

Figure 8: Proficiency Assessment Results

A career path constitutes of an individual's education, training, and experiences that he/she has been through and the tool provides a visualization of the entire career path. The individual will have to enter each position's Lifecycle Stages, Roles, System Types, System Scopes and Domains. The tool will showcase this data in a tabular form to have a better view of these career paths, as shown in Figure 9.

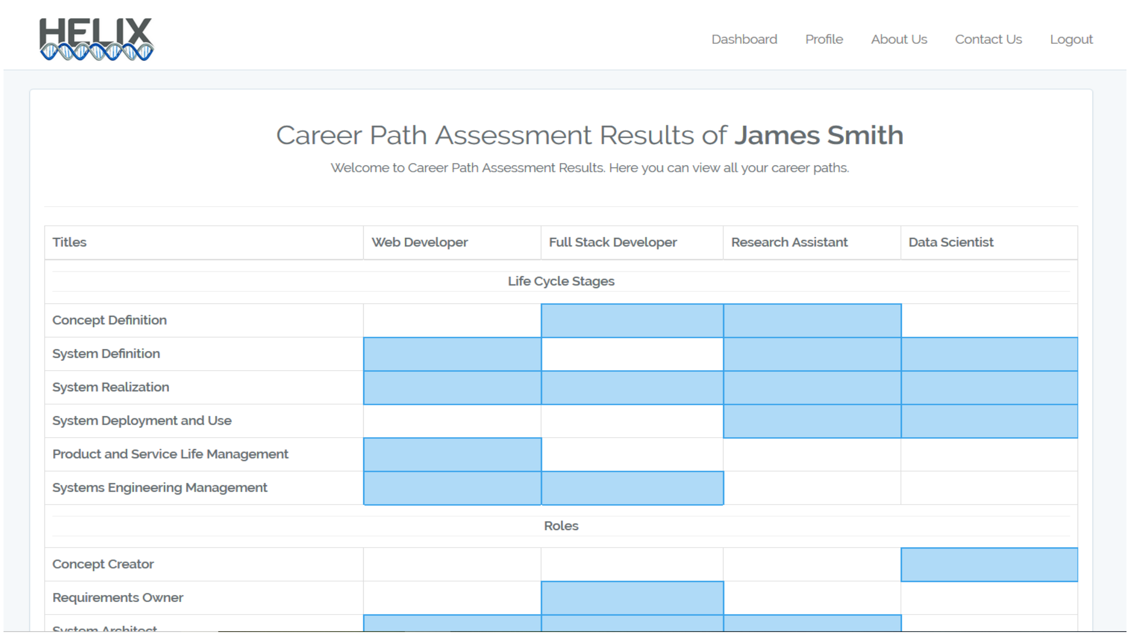

Figure 9: Career Path Assessment Results

The admin dashboard is an interface designed for the application administrator to visualize and manage the data of the tool, as shown in Figure 10. It gives a general idea of how the users of the tool are using the web application. The admin will have oversight of the following:

- Number of users that have given their consent to use their data

- Number of past, present and future proficiencies entered into the system
- Number of current career paths entered into the system

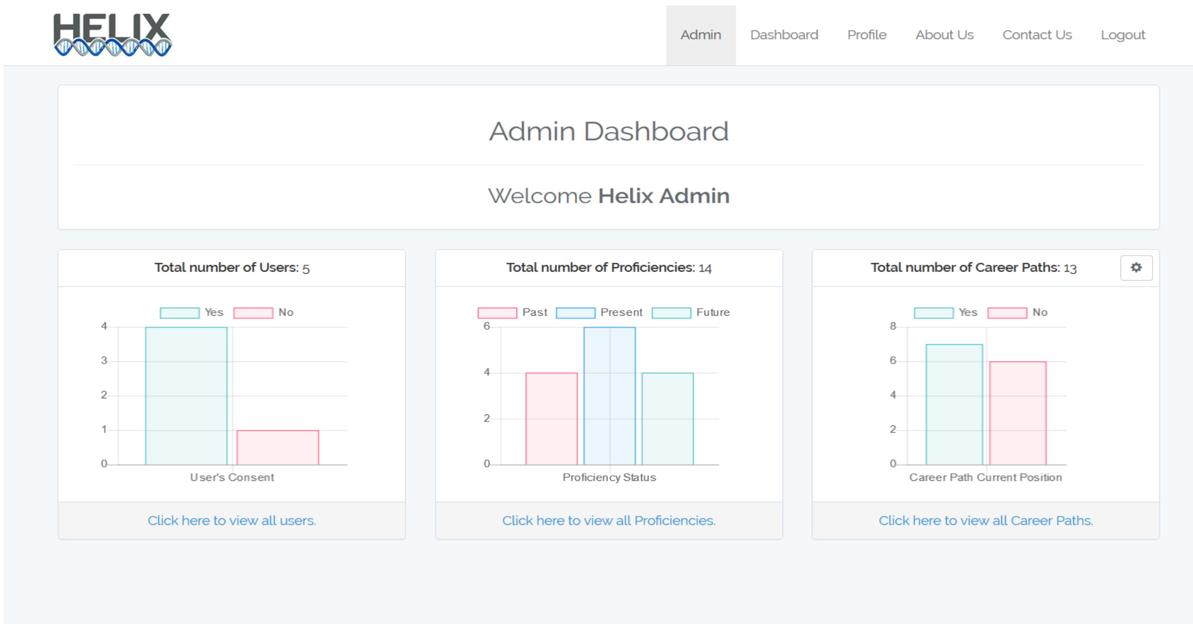

Figure 10: Admin Dashboard

The admin will also be able to perform the following operations:

- View, update or delete the user's data
- View the proficiencies and career paths of the users that have given their consent
- Edit the options and definitions in the Career Path Assessment Form

The self-assessment tool is currently available to the public on the Helix website: http://helix-se.org/participate

3.4 Diversification of the Dataset

The team is adding organizations that are culturally different from existing organizations, in domains that are currently lightly represented, or which provide different approaches for systems engineering. For example, the team is working with one team that is focused on rapid prototyping and is working to bring in a team that has heavily and successfully used model-oriented approaches.

In addition, through separate funding, the team added five organizations to the sample from the Netherlands to test the cross-cultural methodology and draw comparisons with non-U.S. based systems engineering organization cultures and practices.

3.5 Data Mining

The team is using new techniques to analyze the existing interview data, including natural language processing and mining for data visualizations. These techniques enable a different approach to analysis the data and will help to validate existing findings as well as identify where qualitative and quantitative methods provide different types of insights into the dataset. The data model is intended to enable organizations to understand their effectiveness in terms of systems engineering and to provide a visual representation of the critical variables – topics identified from the interview transcripts. This study demonstrates the views and opinions of the interviewees in the forms of plots, graphs, and dendrograms. The data categorization is based on the types of organizations and subsequently sorted further by the interviewee's answers. The modeling approach will focus on extracting cultural traits in an organization and their effects on the performance of the systems engineering workforce.

The data collected through the in-depth interviews is in a free text format. Operations for text analytics are being conducted in Python using Natural Language Toolkit (NLTK). NLTK is used to manage, explore, and analyze texts through its built-in algorithms. It contains text-processing libraries and also includes graphical representations to show results from the analyses. Figure 11 illustrates the overall approach developed for data analysis in this study. The objective is to search for suitable topics and provide them as an input to the data visualization graphs to address the research questions.

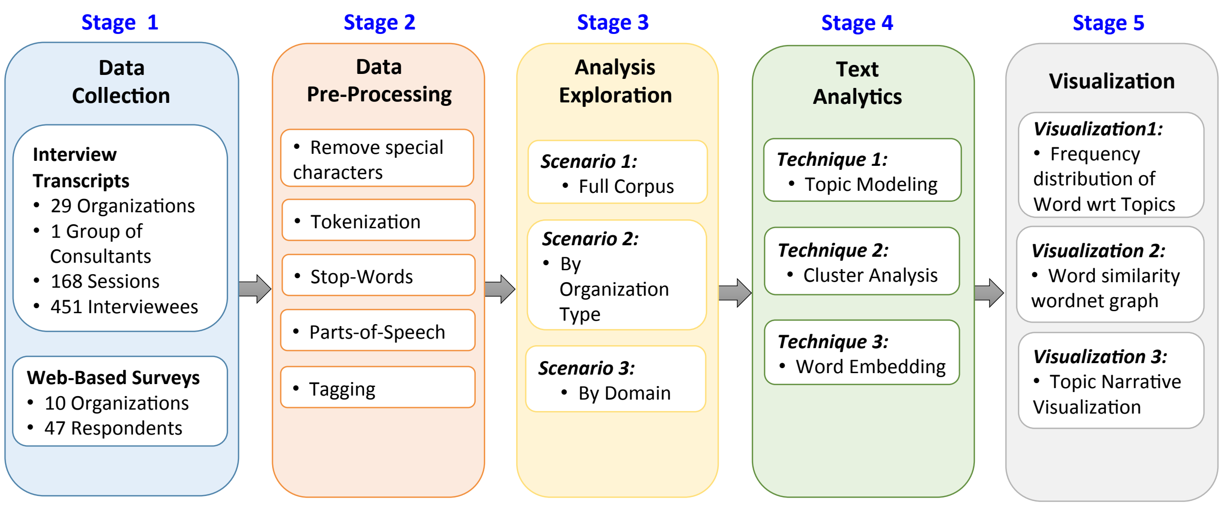

Figure 11: Helix Framework for Data Mining and Visualization

Stage 1 is the data collection phase, which compiles the data from interview transcripts as well as free-text responses to the Helix survey instrument. The first approach will be focused on the analysis of the data obtained from the interviews. Stage 2 involves the data pre-processing phase to perform tokenization, removal of stop-words, and others. The purpose of this stage is to refine the data by removing unnecessary information and utilizing the significant words derived after preprocessing for text analysis. Stage 3 provides the details of how the data can be explored using different approaches by considering the full corpus, slicing the data by domain and by organization type. Stage 4 includes the text analytics process, which currently includes three approaches: topic modeling, cluster analysis, and word embedding. Stage 5 creates visual representations of the results obtained from Stage 4. Finally, Stage 5 incorporates three different approaches for visualizations such as frequency distribution of words with respect to ("wrt") topics, word similarity WordNet graph, and topic narrative visualization. Each stage will be further explained in the following sections.

3.5.1 Stage 1: Data Collection

The data collection process began in June 2013. The data used in this work was gathered from of 464 individuals working as systems engineers (90%) and their senior leadership and peers (10%) across 29 organizations and a group of consultants. The Helix project was initially focused on data collection from the Department of Defense (DoD) and the Defense Industrial Base (DIB), but the current data includes information collected from organizations in the healthcare, transportation, telecommunications, and non-defense aerospace domains.

A) Data Collection Techniques

The primary data source for this analysis was obtained through in-depth interviews with systems engineers, their leadership, and their peers. Interviews were conducted for either 90 or 60 minutes either individually or in small groups of individuals in related positions (i.e. systems engineers with other systems engineers, managers with other managers, peers in separate groups, etc.) Peer interviews provided external verification on the insights from systems engineers as well as their work and roles in the organization. Where possible, interviews were recorded, and a transcript was created from the recordings. Where this was not possible, the team took as detailed notes as possible and created an interview summary with as many direct quotes as possible. When participants were willing, follow up interviews were also conducted, and these transcripts were also included in the dataset.

B) Data Description

The participating organizations are classified into three categories: government, industry, and Federally Funded Research and Development Centers (FFRDCs). Also, these organizations can be grouped into multiple domains such as defense, healthcare, transportation, telecommunication, and IT.

3.5.2 Stage 2: Data Pre-processing

Data pre-processing is one of the most critical stages in data analytics as it includes cleaning the datasets to further simplify the process. Data pre-processing includes a series of steps to be conducted such as cleaning, tokenization, tagging of words, and forming the n-grams. The detailed descriptions of the above-mentioned processes are as follows:

1) Data cleaning: The names of interviewers, interviewees, and organizations are removed from the interview transcripts to protect their privacy and confidentiality.
2) Tokenization: The text or the given dataset needs to be segmented into paragraphs, sentences, words, and also numbers before any kind of application of data pre-processing. This process is known as tokenization. NLTK includes various built-in libraries for performing the tokenization on paragraphs, sentences, and words.
3) Removal of stop-words: Stop-words are common words, which are less significant or carry lesser meaning as compared to other symbolic words. To avoid the redundancy in the data and to obtain efficient results, the stop-words are removed from the data. There is a built-in list of stop-words in NLTK under 'English', but the list can be updated with our own set of less important words. In the interview transcripts, there are

multiple words related to systems engineering which are used frequently that are included in the updated list of stop-words. For example, the words, 'systems engineers', 'helix', 'I', and so on. Also, acronyms were identified to avoid including them as stop-words such as "eeo", which means equal employment opportunity.

4) Tagging of words: In this step, words will be classified into their parts of speech (POS) and labeling them is known as POS tagging or simply tagging.
5) Regular expressions: To process a particular content, its format and markup of the strings forms the central task in most Natural Language Processing (NLP) operations. All of these string processing use the regular expressions. There are a few building blocks in simple regular expressions such as wildcard, optionality, repeatability, and choices.

3.5.3 Stage 3: Analysis Exploration

To obtain meaningful results that could categorize the data and generate clusters of similar words, the next set of guidelines need to be followed. The data needs to be opinionated to understand the mindsets of the interviewees, which will further develop the data model structure. The techniques are described as follows:

A) Categorization

The data is categorized based on the organization type and subsequently on the basis of the individuals providing the responses during the interviews. There was a set of questionnaire/topics for the individuals in each group. The interview questionnaire focused on the following topics: overview of systems engineering in an organization, exploring proficiency, role, characteristic, and activities related to systems engineers, exploring organizational attributes and cultural changes related to the systems engineering workforce. There are three different approaches to categorizing the data based on the interview transcripts. After considering the three categorization approaches below, the team can proceed to the next stages:

1) Consider the whole content of the corpus produced after data pre-processing and apply further progression in this newly formed dataset,
2) Slice the interview transcripts according to their respective organization type such as Government, Industry, and FFRDCs, and
3) Segment the transcripts by the 29 organizations and a group of consultants.

3.5.4 Stage 4: Text Analytics

The process of analyzing the text is completed at this stage. It showcases three kinds of methodologies to analyze the text (in this case, corpus).

A) Topic Modeling

The team classified corpus generated from the pre-processing stage into numerous topics for developing the frequency distribution of the words for the WordNet graph. With this intention, the team used the technique known as LDA for topic modeling. LDA represents the documents (corpus from interviewees' answers) as a mixture of topics that give out words with certain probabilities. The main goal is to find short descriptions of portions of corpus that enable efficient processing of large collections while preserving those crucial statistical relationships which are useful for basic tasks such as classification, creative detection, summary formation and similarity, and making relevant judgments.

B) Semantic and Topic Narrative Clustering

With the intention of identifying and visualizing conversational patterns from the interviews, the Helix team will implement the semantic and topic narrative clustering techniques to obtain a summary of contents or the articles provided to the tool as the input. It also provides a visual representation of the topics contained in the text. This approach proposes three different methodologies to model the narrative structure of a text as follows:

1) Based on the chronological appearance of words in the text: This helps in revealing any temporal feature such as repetition.
2) Based on the meaning of the words: This reports progression through groups of words having similar as well as different meanings, exposing the themes and advancement of the text.
3) Based on the topic that each word refers to: This also reveals the topics that were mentioned in the text.

C) Word Embedding

In order to uncover hidden word-relationships within the dataset, the team is exploring word embedding, specifically Skip-Gram as described by Goldberg and Levy (2014). In contrast to Common Bag of Words (CBOW), which aims at predicting the word given its context (context meaning dataset), Skip-Gram seeks to predict the context given a word. In other words, Skip-Gram offers a description of the dataset by searching for target words. Examples of Helix target words include: “Effectiveness”, “Culture”, “Organization”, “Value”, “Processes”, “Structure”, “Role”, and “People”. By using the aforementioned words as targets, the team expects to have a more detailed description of what participants discussed in the interviews.

Gensim-word2vec, proposed by Mikolov et al., has been chosen to implement word embedding as it offers different models to analyze, explore and visualize the relationships among words. (2013) Similar words will be determined via unsupervised training by measuring the Cosine Distance Similarity (CSD) among words. The CSD ranges from 0 to 1, the closer to 1 the stronger the relationship between the compared words.

The Helix model has been coded in Python 3.6 and uses Gensim and NLTK packages as backbones. An example of the expected results from this technique is the following: word2vec suggests that there is a strong relationship between “Culture” and “Productivity”. At this stage, the team is unable to determine what type of relationship exists between the two words. Therefore, the team reviewed the transcripts and discovered that participants mentioned that “Culture” influences negatively “Productivity”. That is when a valuable relationship has been discovered. The results obtained from the analysis stage would be provided as an input to the visualization tools for giving us the similarities between the mindsets of the different individuals and would provide an overall perspective of the questions that the team is addressing.

3.5.5 Stage 5: Data Visualization

This section encompasses all three visualization methods selected for the representation of related datasets as follows:

1) Frequency distribution of words with respect to (wrt) topics: This design displays a distribution of the words occurring in each topic associated with their respective organizations. It is attained by calculating the ratio of the number of words in a categorical topic to the total number of words in the corpus. Using this method, the team can gather the most frequently used words related to a particular topic.
2) Word similarity WordNet graph: This method is used for the visualization of the dataset. The word similarity graph produces a graph, which calculates the degree of semantic similarity between the words of topics generated from an interviewee's answers and words of similar topics generated from the rest of the interviewees' answers. This generates a graph to show how many interviewees have a uniform mindset in correlation to a specific topic or question.

4: Results

This research resulted in preliminary analysis and findings from the surveys that were launched in late Fall 2018, and also findings from the text analytics and visualizations of interviewees' responses from over 6,500 pages of transcripts and notes. The following subsections provide the detailed findings from this research. These findings will be updated as additional data is collected in 2019.

4.1 Survey results

The surveys are focused primarily on enabling detailed data collection across the draft *Atlas*^{ORG} framework as outlined in Figure 2. A synopsis of overarching survey results can be found in Appendices G and H. Below, results on a few key questions are incorporated and an example of data from one organization is provided to illustrate the types of relationships the Helix team is exploring and will continue to explore as additional data is collected.

4.1.1 Systems Engineering Effectiveness

One of the biggest challenges the Helix team has faced to date has been how to define systems engineering effectiveness. The interviews collected through January 2018 were focused primarily on the effectiveness of *individual* systems engineers. The qualitative data led to the values systems engineers provide as highlighted in *Atlas* (Hutchison et al., 2018):

- **Keep and maintain the system vision.** Get the true requirements from the customer, see relationships between the disciplines, help team members understand those relationships, and provide the big picture perspective for the system. This involves understanding the system vision and explaining it well to the team in a way in which each team member understands their contribution to realizing the vision.
- **Translate technical jargon into business or operational terms and vice versa.** Translate highly technical information from subject matter experts into common language that other stakeholders can understand, as well as translating operational concepts, customer needs, and customer desires into language that makes sense for both engineers and program managers.
- **Enable diverse teams to successfully develop systems.** Bring together a diverse team of engineers and subject matter experts; understand the strengths of each team member and draw on those strengths; rally the team around the common vision; identify and address areas of concern for team integration.
- **Manage emergence in both the project and the system.** Project into the future, which includes staying "above the noise" of day-to-day development issues; communicate the future well to aid decision making that leverages positive emergence and minimizes negative emergence.
- **Enable good technical decisions at the system level.** Balance technical risks and opportunities with the desired end result; leveraging the system vision and a solid grasp on the customer's needs in the application of strong problem-solving abilities – particularly the ability to focus on root cause rather than proximal cause.
- **Support the business case for the system.** Balancing traditional project management concerns of cost and schedule with technical requirements; understand and communicate well the position of a system within the organization's or customer's portfolio.

When asked about metrics for a systems *engineering* effectiveness, respondents struggled with ways to measure the above. When pressed, the majority of respondents highlighted the "iron triangle", stating that if projects are delivered on schedule and on budget and with sufficient quality, then that is a good indicator that systems engineering is working well. However, this metric can also be used for project management and other engineering disciplines and, as many participants who referenced the iron triangle stated, even with effective systems engineering other factors can cause projects to go over cost, beyond schedule, or to fail meet technical goals. The Helix team is working to create metrics that are specific to systems engineering.

In 2007, the Software Engineering Institute (SEI) and NDIA conducted a study comprising of case studies and a survey of systems engineering effectiveness. The goal of this study was to identify the degree of statistical association between the use of specific systems engineering practices and activities on projects, and quantitative measures of project performance (Elm et al., 2007).

The primary hypothesis of their survey was stated as, "The effective performance of SE best practices on a development program yields quantifiable improvements in the program execution (for example, improved cost performance, schedule performance, technical performance)." (Elm et al., 2007) To assess the application of systems engineering practices to projects, the researchers selected the Capability Maturity Model Integration (CMMI) and extracted all the listed work products and identified work products that result from systems engineering activities. Then, the researchers extracted the work products that are most significant to systems engineering, which included process areas within process management, project management, and support.

In the initial report by Elm et al. (2007), the study demonstrated that projects with better systems engineering capabilities delivered better project performance, but they also mentioned that *systems engineering capability alone does not warrant outstanding project performance*. In addition, the results by Elm et al. (2007) reported some limitations and lessons learned from their experience in developing and implementing their survey as follows:

- The lack of a widely accepted definition of systems engineering need not be an obstacle to identifying SE activities deployed on projects
- Indirect access to respondents helped project confidentiality of respondent's data, but made it more difficult to track progress and to analyze data
- Insufficient stakeholder involvement limited response to the survey

Overall, the initial survey results by Elm et al. (2007) resulted in statistical association with ranked project performance driving factors. Elm et al. also found that the statistical relationship with project performance was rather strong when both systems engineering capability and the level of project challenge were considered together in explaining variation in project performance. (2007)

In the Helix survey, the team asks specific questions around systems engineering effectiveness[4]:

- *Overall, how effective is systems engineering here?*

[4] Note that this is the wording used in the survey for system engineers. The wording for managers, peers, and leadership is slightly different but addresses the same concepts.

- *Please elaborate on your answer to the previous question, with examples if appropriate.*
- *If you could change one thing to make systems engineering more effective here, what would you change?*
- *Specifically, what are the most important things the company counts on you to do and deliver?*

These questions about effectiveness give a Likert scale response on effectiveness, but in many ways the most important responses are the qualitative/free text accompanying this assessment, because it explains exactly *why* an organization is viewed as effective or ineffective at systems engineering. This data, paired with information from the interviews, provides a rich picture of the participants' views on systems engineering effectiveness.

As of the publication of this report, the responses to the Likert scale question are illustrated in Figure 12.

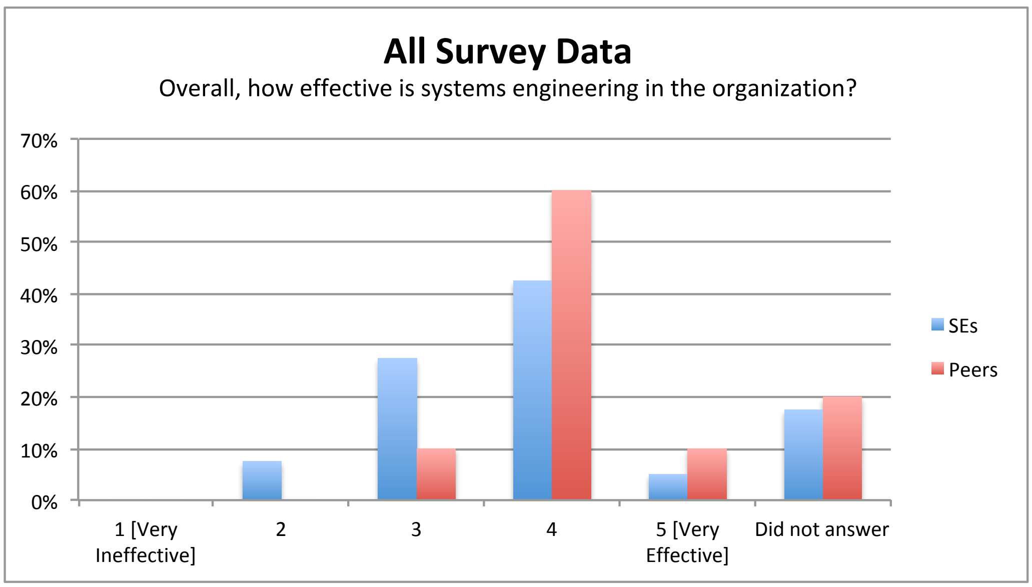

Figure 12: Survey responses on systems engineering effectiveness.

The ratings themselves are self-explanatory, but what is more interesting is the differences between the responses of systems engineers and their managers, peers, and leadership (listed in Figure 12 and discussed in this report simply as "peers" for simplicity). Overall, systems engineers judged the effectiveness of the discipline in the organization to be lower than their peers, with a higher percentage of systems engineers reporting that systems engineering effectiveness is "neutral" in their organization than peers, and likewise, peers were more likely to highlight systems engineering as "effective" than the systems engineers themselves. Responses of individuals who provided context for their answers are highlighted in Table 2 below. Comments that may be related to metrics for systems engineering effectiveness or related to the variables highlighted in Table 2 are highlighted in **bold**.

Table 2: Examples of systems engineering effectiveness ratings with survey respondent elaborations.

Rating	SE Elaborations	Peer Elaborations
2	• Systems engineering is ineffective here today, because it is **underutilized and undervalued by senior leadership**. However, we are already seeing signs of that turning around finding an increasing level on desire for engineering practices. The more that paradigm shifts, the more effective the engineering will become. • In its infancy with a heavy requirements and risk focus, systems engineering in the organization is susceptible to the "garbage in, garbage out" phenomenon.	• N/A
3	• We build great systems, but the connection and **success with the market** is too little. • It depends on the program and when SE is engaged. If **systems are active early, we are effective**, if they are brought in as firefighters we struggle. • In the end we manage to develop new complex systems, although it can be **more effective by using the same technologies, architectures and designs in multiple projects.** • Hindered by process and tools. SE **practices are not consistent among entire organization**. • Difficult to benchmark. Certainly, system engineers have very important role within product development but **increasing quality of their output upfront** would benefit overall development efficiency.	• N/A
4	• We could be better, but most of our gaps don't seem to be due to SE. (Other than maybe my earlier comment on interface issues) • Priority setting (i.e. select which tasks NOT to address). Good cross project synchronization. Good req. management tool. Processes pretty well described and a **culture to use the process descriptions to "support" tasks, not as a rigid framework**. • For the Projects where **SE is supported by Project leadership, SE is effective** at **reducing risk and late stage change**.	• So far, we have managed to deliver most product and projects on time, schedule and budget. Because our **System Engineers are pragmatic, take risks, and tailor the process and tools if necessary**. • We are in good shape compared to many other environments we know. However, we can be better, and we need to be better. • We manage to run **highly complex technology projects in the set time frames** • Without [SE], we can't make the products and **deal with the complexity**
5	[We are] well-known for high quality solutions/products.	• N/A

Though data collection is ongoing, a few things stand out from these preliminary results. In particular, a few of the values that systems *engineers* provide are translated into indicators of systems *engineering* effectiveness. Managing complexity (which is strongly related to emergence) is highlighted by both systems engineers and those they work with and systems engineering's role in managing risk is highlighted. The role of systems engineering in aligning systems with the business cases are also highlighted. The Helix team will not over-interpret these insights with only 25 data points providing additional comments on effectiveness. However, these initial responses indicate that the survey results are likely to provide a solid foundation for establishing a way to assess effectiveness of systems engineering.

The follow up question, "If you could change one thing to make systems engineering more effective here, what would you change?" is also insightful, as the address areas where systems engineering is currently less effective than desired. The responses of systems engineers and their peers are provided in Table 3.

Table 3: Examples of systems engineering effectiveness ratings with survey respondent elaborations.

Category	Systems Engineers	Peers
Business Case	• N/A	• Create better alignment between technology and business strategy.
Clarity	• Clarify functional ownership in the total system. • Role clarity.	• N/A
Coordination	• N/A	• More cooperation between different disciplines. • Merge hardware/software system engineering teams.
Customer Focus	• Design systems better suited for the customer, more successful in the market.	• System Engineers should be more involved or know more from the customers needs and problems. System Engineers should spent more time in sorting out engineering issues before signing a contract. • Increase the natural leadership of the architects More awareness for product value
Decision Making	• Clarify governance on decision making to speed up decision making.	• Knowledge and decision management in model based tooling.
Empower Systems Engineers	• N/A	• Empower them more, and provide them with sufficient budget to pursue investigations they believe are worthwhile.
Modularity	• Using the same technologies, architectures, and designs in multiple projects.	• N/A
Portfolio Planning	• Roadmapping process now feels like filling the shopping basket for the business unit. It should be an integral process with the business unit and R&D. This would also result in a more stable roadmap. • More focus on long term, less focus on projects.	• Portfolio focus

<table>
<tr><th>Category</th><th>Systems Engineers</th><th>Peers</th></tr>
<tr><td>Process/Tools</td><td>Look more for tooling supported systems engineering. But it is important that the tools are and stay an aid and not become a goal by itself.
Introduction of MBSE for architecture, system design and its interfaces.
Better sharing of successful approaches/best practices.
Having a community that shares best practices, way-of-workings, etc would help.
Perhaps some tools require serious efforts (like model based design), that would require dedicated teams (separated from projects).
Involve other disciplines more directly in the process.
Less meetings on processes and schedules.</td><td>More upfront design validation, too much "don't knows" in projects.
Improve on test automation.
More cross-disciplinary & cross-project application of model-based approaches
Model-based architecting
Left hand side of the V:
More formal methods and models
More formal specification of non-functionals
More formal ways of decomposition
More use of simulations
Decompose smarter (move towards systems of systems with clearly defined interfaces and independent release cycles)
Right hand side of the V:
More test automation
More frequent, earlier integration
Clearly identify integration as a competence
Data driven test result analysis to help optimize and prune test efficiency
Agile way of working
Knowledge and decision management in model based tooling
Better use of model based system engineering</td></tr>
<tr><td>Workforce Development</td><td>On-boarding of new people in the working methods. Flexibility in the working methods is great, but you should first know the rules before you choose to ignore them.</td><td>Increase the natural leadership of the architects More awareness for product value</td></tr>
</table>

Interestingly, though both systems engineers and their peers in these organizations reported that rightly or wrongly there is a perception of systems engineering being too much about process, the majority of specific recommendations on how to make systems engineering more effective did focus on process. In particular, the use of modeling in systems engineering is highlighted strongly by both groups. This mirrors the interview data in both organizations, where model-based systems engineering (MBSE) was seen as desirable, though not always well understood. Though it did not come across strongly in the survey results, systems engineers and their peers at all organizations in the Netherlands discussed the importance of developing a portfolio approach to guide systems engineering, focusing on platform-level capabilities and planned modularity and reuse.

The survey contains five primary questions with elaborations on governance and nine questions with elaborations on systems engineering methods, processes, and tools within the organization. These items include assessing (e.g. “Overall, the way systems engineering is organized here is very effective” as well as more open-ended or qualitative, (e.g. “Which leading edge systems engineering processes and tools are used here?”).

Histograms and word clouds based on the survey data to date can be found in Appendices G and H. A few items are highlighted below with regard to these areas to illustrate the types of ongoing analyses the Helix team is performing. The first item is Likert scale responses to the prompt, “Overall, the way systems engineering is organized here is very effective.” (Figure 13) One thing that is immediately evident is that the peer and systems engineer assessments are fairly well aligned. In the free responses paired with this question, a few patterns emerged: one is that many systems engineers and peers reported that this was heavily dependent on the project or the organization, indicating that in these organization, there is no clear and consistent approach for organizing systems engineering activities. These were the most common comments for both [3] “neutral” and [4] “effective” responses; in general, the responses indicate that when the organization of system engineering activities is clear, then it is more effective.

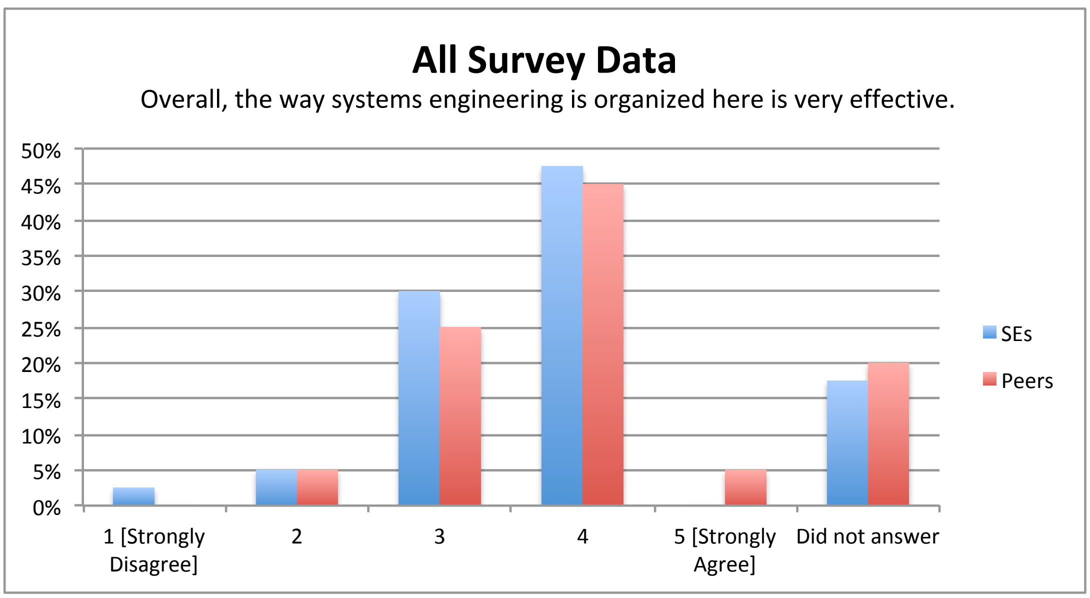

Figure 13: Systems Engineering Organization

Systems engineering is often associated closely with the processes used to perform the work. The survey specifically asks systems engineers and peers to describe the systems engineering processes used in the organization and to assess how well these processes are working. Figure 14 shows the current status of the results. A few of the free text comments highlight the need to incorporate more data analytics and quantitative models into systems engineering in their organizations and that more effective systems engineering processes are tailored to projects, help identify interfaces between disciplines and different parts of the organization. A common pattern seen through responses to multiple questions is the need to bring systems engineering processes not just to individual projects, but also to managing a portfolio of products.

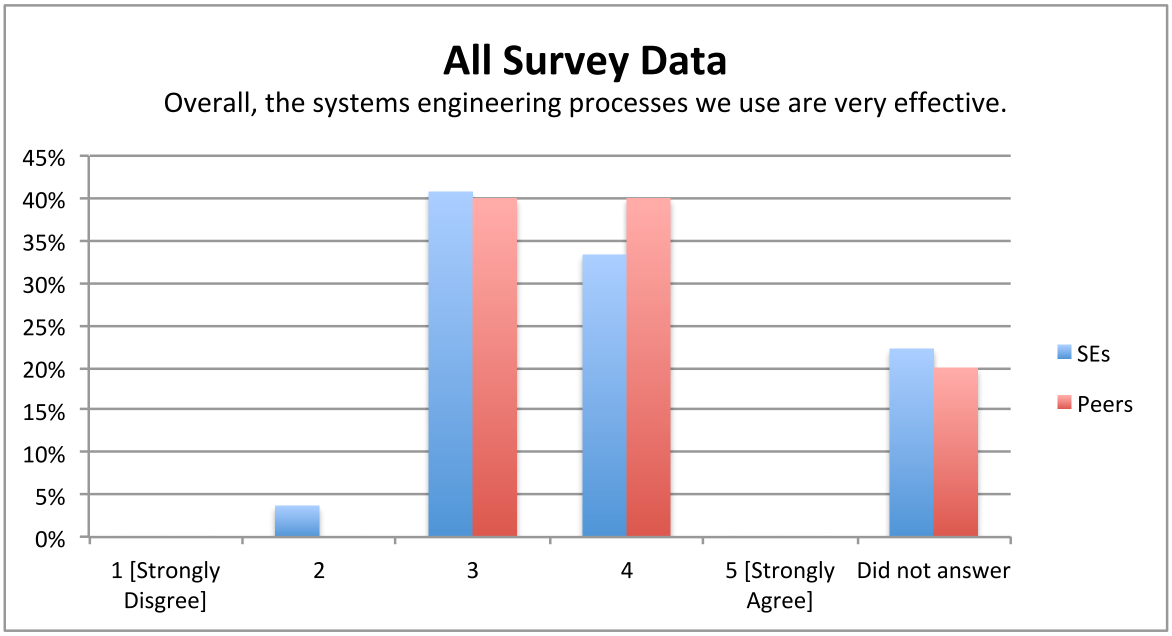

Figure 14: Effectiveness of current systems engineering processes.

The survey also asks specifically about the tools used for systems engineering in the organization as well as whether those tools are appropriate for systems engineering in that organization. Figure 15 highlights the current results. Many of the comments focused on areas of improvements for tools specifically discussed a desire for tool integration and for tools that better support MBSE.

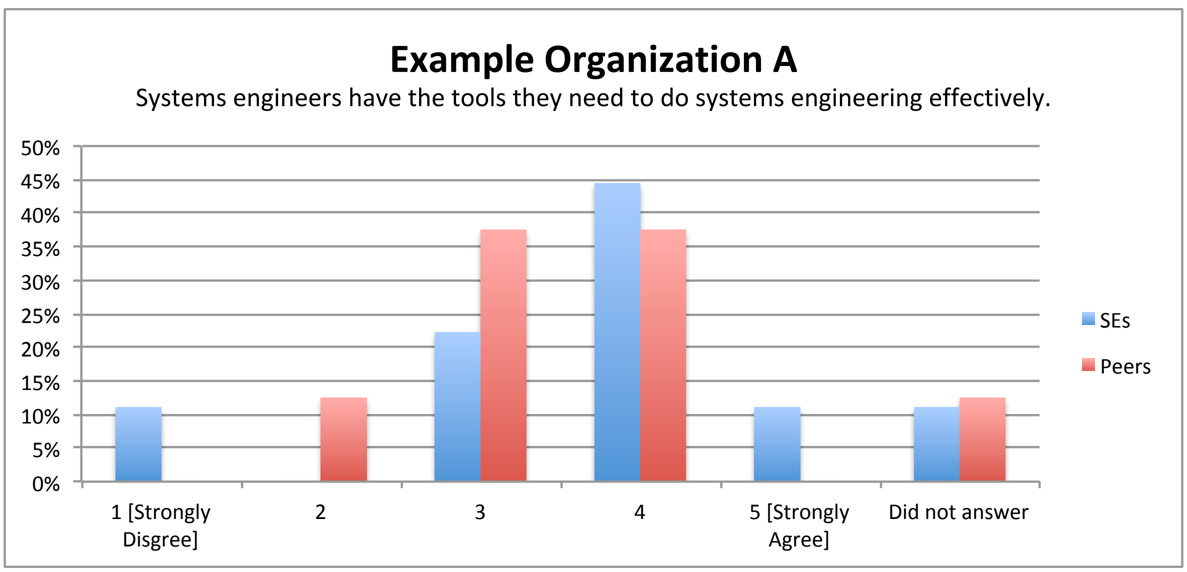

Figure 15: Do systems engineers have the tools they need?

As additional data is collected, the team will align these results with specific types of organization (e.g. strong versus weak matrix versus centralized systems engineering), tools, etc. The goal is to map patterns in these responses against the organizational effectiveness questions to determine the relationships between particular types of governance, how certain types of tools and processes integrate, etc.

4.1.3 Exploring Variable Relationships in an Organization

The purpose of the survey is to collect as many examples as possible of the alignment of these different variables – culture, structure, governance, teaming, systems engineering methods, processes, and tools – with each other and with effectiveness. While looking at the dataset as a whole can help with these patterns, the real power of the survey results is in gathering all data related to an organization, identifying patterns and interaction in that organization, and then comparing those patterns with other similar and dissimilar organizations. To illustrate this, the Helix team has prepared a sample using anonymized real data from one organization, "Example Organization A".

Figure 16 provides a view of the culture for Example Organization A's cultural profile using the Competing Values Framework (CVF). A few things are worth noting in Figure 16. One, the cultural assessments of the systems engineers and their peers are fairly well aligned, indicating that the different groups have similar experiences of the organizational culture. Both groups indicate that Example Organization A's culture is fairly evenly divided between the four archetypes, and both groups indicate a desire to move from this current profile to a somewhat less hierarchical and more innovative culture.

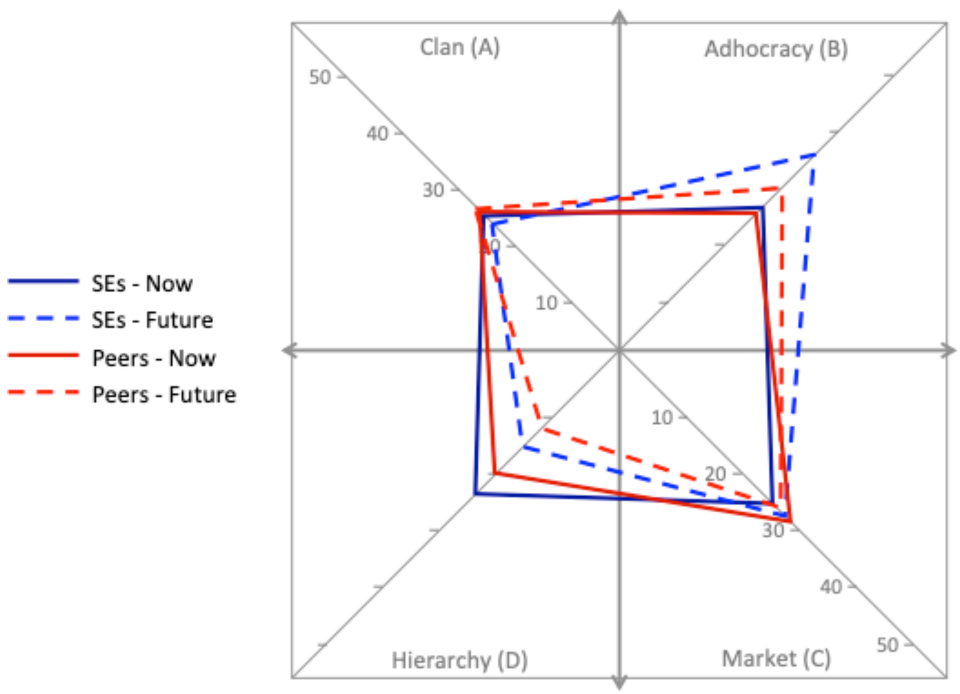

Figure 16: CVF for Example Organization A

The survey also includes the Qi Index (described in Section 3.2.3). For Example Organization A, systems engineers are somewhat less optimistic that the current team culture supports the adhocracy/innovation style compared to their peers.[5] In aggregate on the Qi Index, Example

[5] Note that the Helix team has partnered with Human Insight and has reports for each organization with enough data points that provides detailed teaming insights that is shared with that organization. However, until additional data is collected, the team is keeping the details internally to maintain organizational anonymity.

Organization A survey participants see their team culture as fairly supportive of innovation (and are stronger in this regard than other participating organizations), even though their CVF answers suggest they see themselves as still too internally focused.

The Competing Values Framework OCAI instrument allows organizations to rate their beliefs about each of the four quadrants on six dimensions of culture as described in the methodology section, above. Although organizations may have similar average scores on the four quadrants of the CVF model, their pattern of scores within each of the six dimensions can indicate especially strong beliefs and assumptions that underlie people's behavior in the organization.

In the case of Example Organization A, people see Dimension #6, Criteria for Success, as an especially important dimension requiring change for the future. The systems engineers in the sample believe that increasing the Adhocracy criterion of success, "The organization defines success on the basis having unique or the newest products" an average of 12 points from a current score of 24 to a future score of 36 is important. On the other hand, their peers see a need to decrease the reliance on this criterion for success from a current score of 38 to a future score of 28.

Peers view the Clan criterion of success, "The organization defines success on the basis of the development of human resources, teamwork, employee commitment, and concern for people" to be the criterion to enhance, from a current score of 16 to future score of 24. Systems engineers discount the importance of the Clan criterion of success seeing the need for only a slight increase of emphasis on these behaviors from a very low 13 to a future score of 15.6. Both groups view the Market criterion of success, "The organization defines success on the basis of winning in the marketplace and outpacing the competition," as the most important criterion in the future with SE's rating the criterion 37 and peers rating it 33 for future success.

Similarly, both systems engineers and peers view the Hierarchy criterion of success, "The organization defines success on the basis of efficiency; dependable delivery, smooth scheduling and low-cost production are critical," as less important than other criteria. Systems engineers see the need to de-emphasis this criterion from a current score of 24 to a future score of 11, whereas peers view the current and future needs for this criterion to both be between 15 and 16 points.

Analysis of the six dimensions of the OCAI for Example Organization A gives additional clues about what a strong Market culture should and should not look like in this organization. Although systems engineers and peers rate the Market characteristics overall as a near-second in importance to Adhocracy values and behaviors, within the Market dimensions systems engineers and peers do not want to see an increase in Market behavior related to Dimension #2, Organization Leadership, defined as "The leadership in the organization is generally considered to exemplify a no-nonsense, aggressive, results-oriented focus." In fact, both groups would like to see a decline in these behaviors from scores in the 30's to the mid 20's. Both groups would like to see an increase in Adhocracy leadership behaviors, as described in the CVF OCAI as "The leadership in the organization is generally considered to exemplify entrepreneurship, innovation, or risk-taking."

These examples illustrate the potential value of using the OCAI within an organization to surface areas of agreement and disagreement about the way things work and "should" work in an organization. Cameron and Quinn (2011) found that high congruence or alignment of different among parts of an organization on the four cultural types was often characteristic of high-performing organizations. They summarize, "Having all aspects of the organization clear about and focused on the same values and sharing the same assumptions simply eliminates many of the complications, disconnects, and obstacles that can get in the way of effective performance" (p 85). When complete, the Helix data may show that high or low organization congruence relates to aspects of Systems Engineering effectiveness.

In the interviews, Systems engineers and peers described themselves as "tribal innovators" who valued "being different" and "able to move heaven and earth" making use of the "freedom to do new things" to "take ownership" and "solve problems not do tasks" and to "take risks." These "vigorously held values" relate closely to the strong Adhocracy and Market culture seen in the CVF data. The fact that they also describe themselves as "collaborative" and as using "collective intelligence" as a principle" while operating in a bottom-up, flat project focused culture reflects aspects of Clan culture which were described as "just the way things are" in the Netherlands in general.

Several of their desires for changes that would increase SE effectiveness relate to their stated comfort with and value of Market focus, including the access of Systems engineers to customers, greater collaboration with the business parts of the wider organization, more influence outside of R&D, and making their innovation strategies part of potential road mapping and platform efforts. Although they see a need for better tools and less dependence on "local heroes" or experts, they want structure and process changes to be fit for purpose, not mandated or over generalized, and only instituted in service to their innovation and market goals. The OCAI survey shows there are tensions between their strong freedom-based cultural identity and potential systematic SE process and tool changes. Their stated dislike for hierarchy, formality, imposed structure, and control behaviors have implications for how potential changes are identified, designed, and implemented and monitored.

During the site visit, the participants of Example Organization A described their systems engineering structure as a matrix organization – systems engineers have a central "home" in the organization but are assigned to projects. The survey responses for Example Organization A are highlighted in Figure 17. Neither systems engineers nor peers reported that their systems engineering organization is extremely effective nor extremely ineffective and both groups were fairly well aligned on their views of how systems engineering is organized.

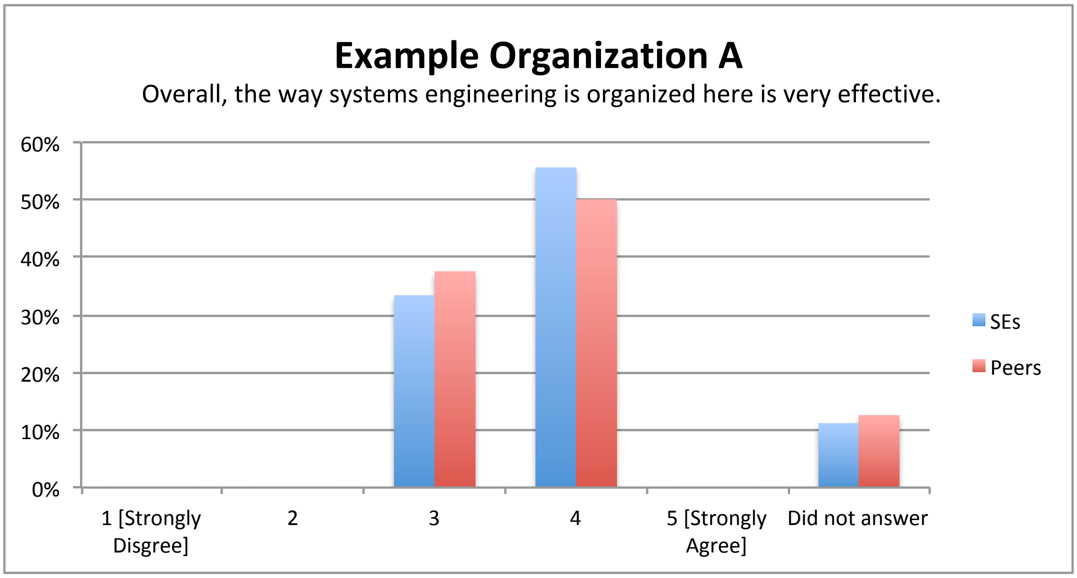

Figure 17: Example Organization A – How Systems Engineering is Organized

Within Example Organization A, both systems engineers and their peers described their systems engineering processes as the "waterfall method".[6] This is a fairly traditional approach to systems engineering and aligns with the "Vee lifecycle model" seen commonly within the US defense industrial base. Figure 18 illustrates the responses on whether or not this approach is effective. Systems engineers were more likely to cite the processes as effective than their peers. A few of the comments from peers highlight the organizational use of this process more than the process itself; for example, "A little bit too dependent on the local hero. We can use somewhat more method but not too much." Also highlighted was then need for application of systems engineering processes to inform the product portfolio; for example, "For single products it is ok, for platform development we will need to organize better."

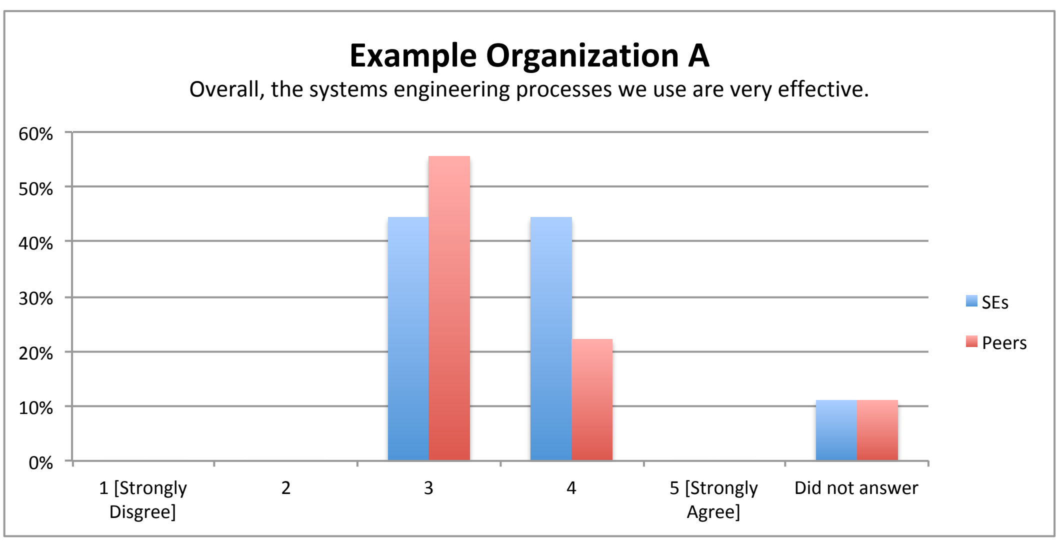

Figure 18: Example Organization A – Effectiveness of SE Processes

For systems engineering tools, the results are shown in Figure 19. Only about half of systems engineers reported they had the tools they needed, while over a third reported being neutral.

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[6] Royce, Winston (1970), "Managing the Development of Large Software Systems"(PDF), *Proceedings of IEEE WESCON*, **26** (August): 1–9

Several comments indicated that they wanted additional tools, but because the company is fairly internally focused, they did not have visibility into what other tools were needed. In feedback from peers, there was a strong recommendation for more MBSE approaches and tools.

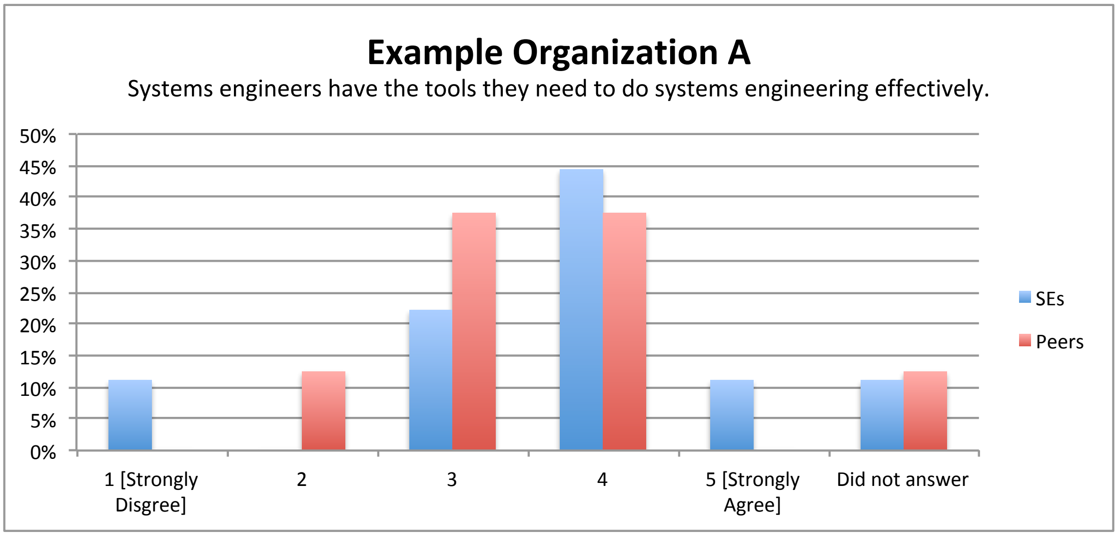

Figure 19: Example Organization A – Systems Engineering Tooling

As with all organizations, respondents from Example Organization A were asked how effective systems engineering is in the organization. Overall, this was viewed as "[4] effective" by over 50% of the participating systems engineers and 75% of the participating peer groups. When asked what they would change (an indicator of what is currently less effective), respondents indicated they would like to see other disciplines more involved directly in the systems engineering processes and that they would like to see more reuse in terms of technologies, architectures, and designs across projects, as well as a more developed community of practice for sharing lessons learned.

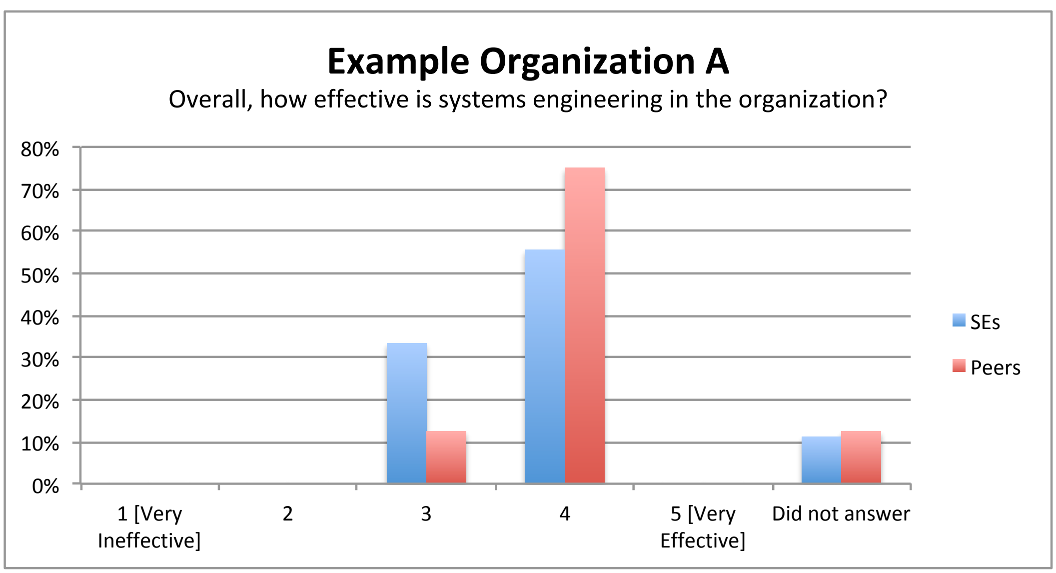

Figure 20: Example Organization A – Systems Engineering Effectiveness

The types of analyses highlighted for Example Organization A will be conducted for all organizations with enough data points. Patterns in each area will be compared with patterns in the other areas, highlighting the relationships between the variables (culture, governance, methods, processes, and tools, etc.) as well as patterns across the variables. For example, the Helix team hypothesizes that certain cultural archetypes within the CVF will be better aligned with certain types of systems engineering processes than others; for example, that agile and rapid approaches may be better supported by the Adhocracy archetype than the Hierarchical archetype and conversely the Hierarchical archetype may be best suited to rigorous acquisition-focused systems engineering processes. Survey information will also be paired with interview data, as highlighted in a few examples above.

From a research perspective, the analysis of Example Organization A demonstrates the potential value of encouraging organizations to use multiple methods to understand their organizational culture and create aligned objectives for change that can enhance systems engineering effectiveness. The preliminary Helix data suggest that the CVF and Qi Index raise meaningful questions for an organization to explore while providing a common language and approach to interpreting interview data. Organizations can use the tools to identify tensions between parts of the organization and to understand the kinds of changes that would be consistent with people's values and behaviors thereby increasing the likelihood that the changes will "stick." Simply discussing the data can itself be a meaningful intervention that enables people to understand their own behavior, uncover ways of using the strengths of their current culture to meet organization goals, and prioritize ideas for change. The tools provide a method for taking stock of "the way we do things around here," questioning assumptions, and making informed choices to affect the future and can be re-used to assess change over time.

4.2 Data Modeling and Visualization Results

The visualizations provide the Helix team with the similarities or differences between the mindsets of the different individuals and an overall perspective of the questions addressed in this research. The interpretation derived from the visual representations will highlight the areas or sectors where interviewees consistently agreed on certain topics. Also, the visualizations will show which common words the interviewees usually use in SE and the relationships between them.

The visualizations will enable the team to compare the differences or similarities between the common languages within system engineering regarding organization type. Two analyses have been performed so far. One in which all the interviewees' answers were analyzed as input for all the proposed techniques, full corpus, and the other analysis was conducted by organization type. In the following sections each approach is represented with visualizations.

4.2.1 Full Corpus

The first analysis approach that the Helix team considered was the entire content of the corpus (interviewees' answers). The LDA approach helped to uncover latent topics in the corpus. The LDA assigns a value that represents how much that answer is related to a specific topic. The LDA was done using a free software, *Orange* (version 3.17), to analyze data. The full corpus has 15,541 interviewees' answers. Figure 21 shows the heat map and the dendrogram of eight topics. The dendrogram was created by using K-means algorithm, which clustered each of the interviewees' answers in one of the topics. The darker the color is in the heat map, the higher the value of that cluster is to that topic. For example, some words that are related to topic 7 are lot, thing, going, time get, way, something, one, people, even. The team can infer by reading several answers that topic 7 is related to "Effectiveness". Of the 15,541 answers, 2,668 are assigned to topic 7, which means that has values greater than 0.45 at least.

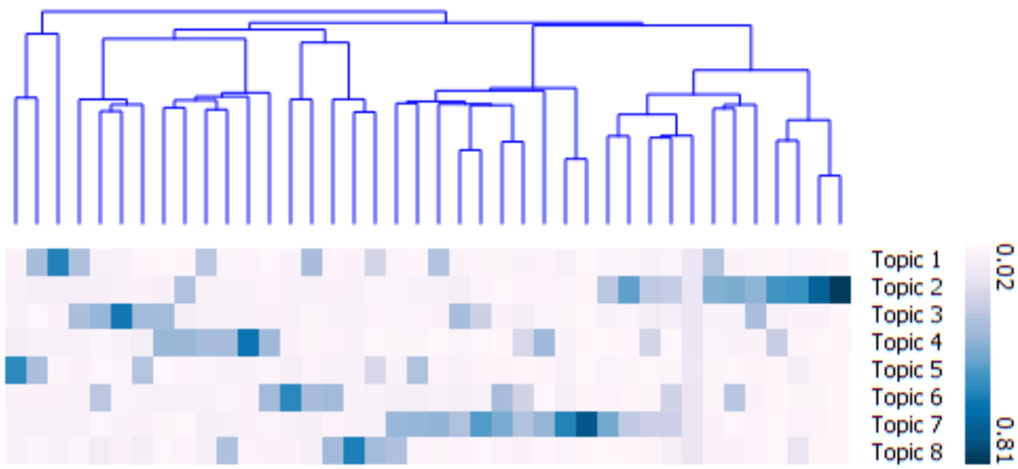

Figure 21: LDA topic Analysis

There are words that appeared in more than one topic because the word is being used in a different context such as a noun, verb, adverb, and so on. By reading several lines of each topic, the team named each topic as shown in Table 4:

Table 4: LDA topics

Topic	Name	Words
Topic 1	Education	team, need, understand, probably, thing, need, take, say, back, way
Topic 2	Government vs. Industry	system, engineer, engineering, think, done, role, kind, one, year, thing
Topic 3	Proficiency	level, technical, got, program, requirement, come, back, make, system, engineering
Topic 4	Experiences	one, project, work, part, job, kind, working, thing, also, role
Topic 5	Personal Characteristics	right, actually, say, see, get, work, project, right, kind
Topic 6	Mentoring	think, good, different, process, experience, year, want, thing
Topic 7	Effectiveness	lot, thing, going, time get, way, something, one, people, even
Topic 8	Background	people, think, organization, much, also, come, much, work, want, different

Topic modeling and analysis of textual corpus with the identification of latent and salient topics, which is based on the frequently occurring words, is what a termite plot does. Termite uses a tabular layout for promotion of the comparison of terms or words occurring both within and across the latent topics. The team uses a seriation sorting algorithm to select salient and relevant terms. Latent Semantic Analysis implements the concept of topic modeling for the production of latent topics, which is represented in Figure 22 and the topics are as follows:

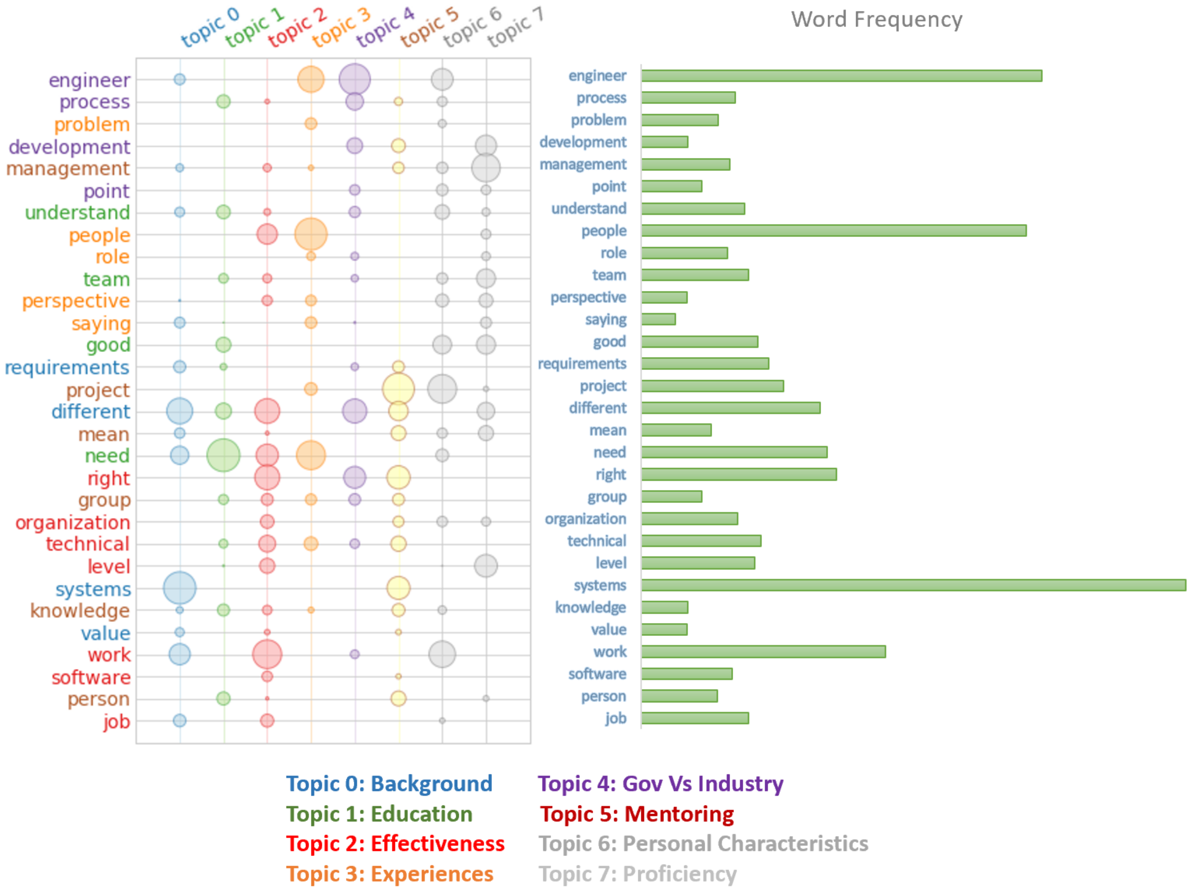

Figure 22: Termite plot for the Full Corpus

Consider an example of topic 2 (effectiveness). The words which are frequently occurring in this topic, such as “right”, “engineer”, and “get”, and chunks of other words like “able”, “different”, “good”, “take”, and “person”. Now, look at the word frequency bar chart, and one will observe that the frequencies of these words is quite high for them to occur in more than one topic. Effectiveness can be interpreted in such a way, engineers are able to get different and right something that makes them effective. Also, effectiveness needs the right person as an engineer. The right side of Figure 22 shows the frequency per word while the left side represents how often each word is presented in each of the topics. The size of the bubble represents that frequency.

The chord diagram displays the inter-relationship between words. The most frequent words are arranged in a circle with the relationship between the data points (arcs). To create the chord diagram, the similarity between two words is calculated by the WordNet library. Then, the path similarity returns a score denoting how similar two-word senses are, based on the shortest path that connects the senses in the is-a (hpernym/hypnoym) taxonomy. The score is in the range 0 to 1. By default, there is now a fake root node added to verbs so for cases where previously a path could not be found - and None was returned- it should return a value. The old behavior can be achieved by setting the simulate root to be False. A score of 1 represents identity i.e. comparing a sense with itself will return 1. In a chord diagram, the width of the band represents how much a word is associated with the rest of the words. Figure 23 shows the chord diagram of the full corpus.

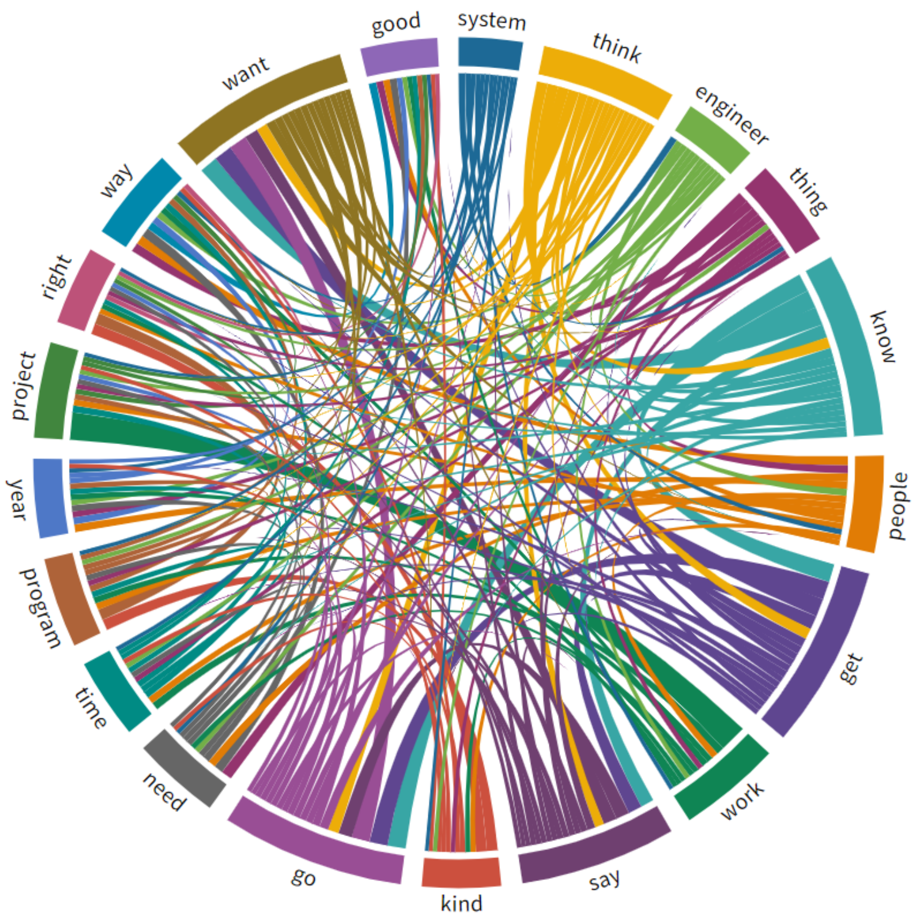

Figure 23: Chord Diagram of the Full Corpus

Figure 24 shows an example of the relationship between the word "work" with the rest of the most frequent words. Based on the width of the band, it can be seen that the word "work" has a strong relationship with the word "project".

Figure 24: Chord Diagram Showing the Relationship between the Word "Work" and other Words

For Helix, one of the critical benefits of this type of data mapping is highlighting relationships in the interview data, which the Helix team can then investigate using qualitative methods. This targeting helps reduce the burden of qualitative methods by enabling the team to focus only on the subset of data that is most relevant. This work is also being conducted iteratively, with additional constraints put on the data – for example, the addition of "stop words" that will not be included in the analysis – on subsequent iterations. For example, several of the words highlighted in Figure 24 ("go", "kind", "think", "get") are likely to be eliminated in future iterations as the team explores the value of these relationships. As these constraints are applied, different types of patterns will emerge from the data. Figure 24 reflects the first iteration, which the Helix team used to assess whether the scripts and algorithms used were behaving as expected.

In regard to word embedding, the team was interested in exploring what terms are similarly associated with effectiveness and culture. To do so, the team implemented a word2vec model specifying "effectiveness" and "culture" as target words and setting the minimum count of words to 5, as it is default in the Gensim model. (2013) The chosen output corresponded to the top 10 most similar words to effectiveness and culture respectively, based on cosine distance similarity. Table 5 presents the top 10 most similar words to "effectiveness" based on the interview transcripts for the full dataset

Table 5. Top 10 similarity words for effectiveness in full helix dataset.

Target Word	Full Dataset Similarity Word
Effectiveness	Urgent
	Innate
	Qualitative
	Agrees
	Tweaked
	Resonate
	Awfully
	Motivation
	Minded
	Analytical

In order to generate insights from the trained model, it is necessary to review the transcripts by targeting the similarity word. For instance, the model indicates that "effectiveness" and "urgent" have a certain relationship, but it does not indicate what type of relationship this is. Therefore, by reviewing the transcripts, also called context, the type of relationship can be inferred. For instance, a few anonymized examples are presented on how interviewees relate to effectiveness by using the target words include:

- *"So I've seen a wide range of the acquisition life cycle. So what has enabled me to keep going is that I've successfully worked on teams that have done full material releases, and **urgent** material releases into theater"*
- *"I'd say those two things are probably the most important. It was a mix. So in two cases, I selected them because I saw **innate** talent."*
- *"I believe a measure of effectiveness of a systems engineer could be both **qualitative** and quantitative"*
- *"I find it very hard to measure the effectiveness of a systems engineer. I think it's 90% **qualitative**, 10% quantitative."*
- *"Yeah, I **resonate** with that. I think some of the best systems engineers that I work with are people that are able to make connections. Either connections among the right disciplines to bring to a problem or connections to a customer need a potential solution or connections between technologies and needs."*
- *"You need to have both the good **analytical** mind to be able to compose things but you also need to be have the imagination and the conceptual prowess to be able to envision things that have not even occurred. And so it's an art and a science, and it requires a certain personality."*

Therefore, from the above excerpts the team could conclude that effectiveness relates to systems engineers in the way that these are able to work on teams, present innate combination of qualitative and quantitative characteristics including being good in communicating, listening, coordinating activities, as well as having the analytical ability to compose systems. The outputs of effectiveness at the full dataset corroborates previous results identified by the Helix team indicating the some of the characteristics of effective systems engineers.

In the similar manner to effectiveness, the team use "culture" as a target word aiming to have a general understanding of how culture is being used within the transcripts. Table 6 illustrates the 10 most similar words to effectiveness for the overall dataset.

Table 6. Top 10 similarity words for culture in full helix dataset.

Target Word	Full Dataset Similarity Word
Culture	Personality
	Interest
	Challenging
	Tremendously
	Helped
	Differently
	Comfortable
	Style
	Smarter
	Ego

In the case of culture, a few anonymized excerpts include:

- *"I'm a flaming extrovert. I'm a moderate intuitive, I'm a moderate thinker, and I'm a strong judge. The most common inside the military profession is INTJ. But when you look at the stratification of those that go into the combat arms, like the infantry or the armor, they are the extroverts of the population - very biased in the extroversion. And so while Myers-Briggs* ***personality*** *test was not really approached scientifically, it does fit very nicely"*
- *"I think the problem right now is a lot of its driven by* ***personality*** *and if I'm going to keep young people here it should be driven by the discipline and the process. This guy knows everything versus then this guy knows everything then this guy knows everything. So what happens is you get young people coming in and they say they're experts in network technologies and they go to the information management organization and they tell them, "No, this is the way we do it here and that's the way you're going to do it."*
- *"Doing different things has always been an* ***interest*** *of mine so being at the systems level, what we would call kind of a project engineering leadership, you get to touch a little bit of everything. Again, you get to draw on those different parts of the organization pulling together."*
- *"And that's* ***challenging****, I think that's challenging throughout the industry. I mean there are some leaders out there… I think they've done a good job with that kind of stuff. But a lot of the other technical communities that I've been in, it's been a real battle to understand do you need leadership with systems engineering oversight or do you need a baseline technical expert in a management role?"*
- *"… having a network of people to support your view or to help correct your view perhaps, because I am learning every day. I do not have it all figured out - the more I'm in this business, the more I find out that I don't know. So that network of people really does help* ***tremendously*** *to be successful as a systems engineer."*
- *"So that has helped me* ***tremendously****. The other thing is, there's a lot of training within the organization; and it has historically been, like a manager factory. So we have a lot of training*

geared around interacting with teams, leading discussions, active listening, things like that, that were very helpful in growing myself past the point of there's my opinion."

- *"And also some of it could just be stylistically - communication is very key, everyone has a different communication styles. Some* ***styles*** *are more effective than others, so there's always, part of that falls in to the one on one counseling too, so maybe this is the better way to approach the situation."*
- *"A lot of its own* ***style*** *but we do have a mentor training program you go through as soon as you start to have someone who you are going to be mentoring and we have an intro to mentoring and all that stuff here"*
- *"The system engineer might be expert in one or two or more technology domains but because of the task that he has to carry on, he has to think broader and let those [SME's], if they have point solutions or something that is more precise, let them work on that. Therefore, he has to be able to work in a way that* ***egos*** *don't come in the way."*

Thus, according to the interviewees, it can be inferred that the military culture differs based on the status level. In addition, a frequent role of systems engineers consists of coordinating with individuals of different personalities, this role has been previously identified by the Helix team when expanded from Sheard's findings. Lastly, in general terms one of the factors that influence the culture of an organization relies and is shaped based on mentoring programs that are offered across the enterprise. From such excerpts it can be extracted that there is not a single culture that influences systems engineers, thus a more comprehensive analysis is required to generalize such assertions.

Once the general dataset has been evaluated, the team aims at identifying similarities and difference at the organization type level. The next section introduces findings based on whether the organization is government, industry, or FFRDC.

4.2.2 By Organization Type

Figure 25 shows the termite plot by organization type with 30 terms. Based on the Government termite plot, topic 3 and topic 5, which are "Experiences" and "Mentoring" respectively, are the topics with more terms within the 30 selected terms. However, topic 5 is more representative for Industry. For FFRDC it seems that the topics are even. This might be because the corpus was not as big as the Government or Industry. The team observed that one topic of an organizational type does not contain the same terms within the similar topics of any other organizational type. For example, Topic 1 (Education) of Government has words, "need", "company", "engineer" and "important", while FFRDC has the terms, "fact", "build", "background" and technical under Topic 1 (Education). Also, in Topic 2 (Effectiveness) under Industry, there are terms, "systems", "engineer", and "analysis", whereas if we observe the terms under the same topic in Government, we have a few different words like, "job", "design" and "people". Every organization has different context with respect to the topics generated for that particular dataset.

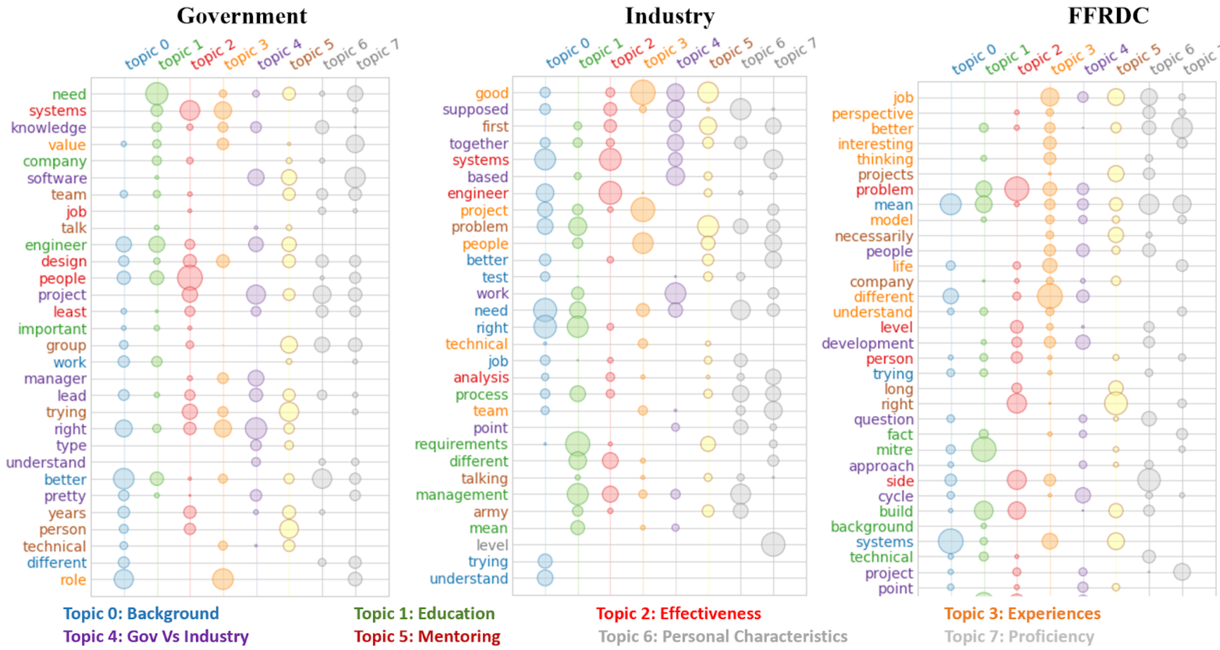

Figure 25: Termite Plot by Organization Type

Figure 26 shows the side-by-side comparison of the three chord diagrams by organization types (government, industry and FFRDC). There are several important relationships in each type of organization. For instance, for the Government organization type, the word, “know” has relation with all the words but not all the words have a relation with “know”. The same happens with the word “think” and “systems”. As mention before, the width of the band represents how much a word is associated with the rest of the words. In Government and Industry organization types, the words “know”, “get”, and “want” have wider bands, while in the FFRDC, the words with wider band are “get”, “go”, and “see”. There is a strong relationship between the words “project” and “work” for both Government and FFRCD, but the word “project” does not appear as a frequent word for Industry, but the word “team” appears only in Industry. Figure 26 shows the side-by-side comparison of the three chord diagrams by organization types (government, industry and FFRDC).

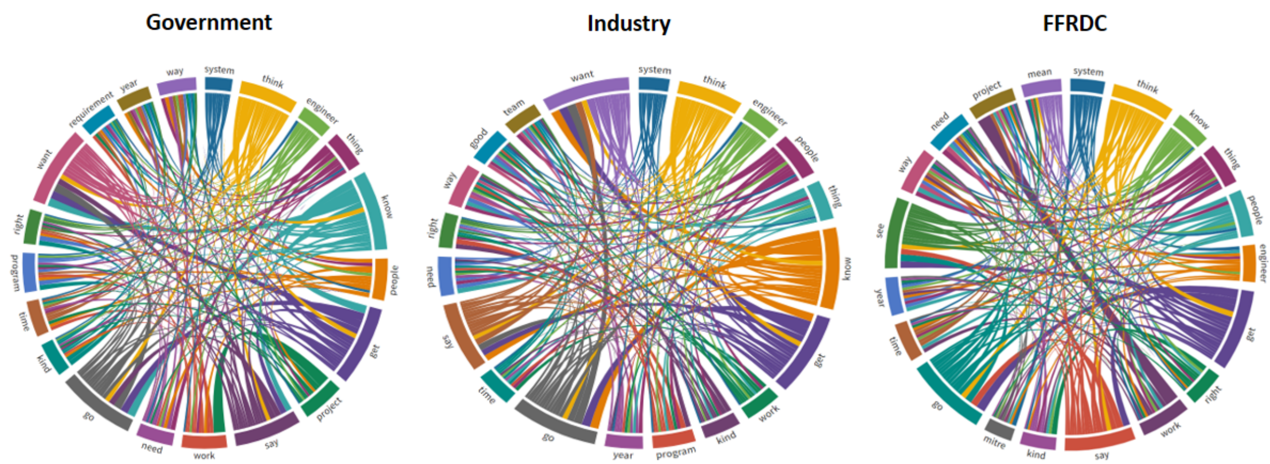

Figure 26: Chord Diagram by Organization Type

Similar to the data visualization approach previously presented, the word embedding model was trained for each of the three organization types described. The main objective is to identify patterns and characteristics for each organization type. Table 7 presents the 10 most similar words to effectiveness for each organization type.

Table 7. Top 10 similar words to effectiveness and effective in the government, industry, and FFRDC organizations types.

Target Word	Government Type Similarity Word	Industry Type Similarity Word
Effectiveness	Integration	Helped
	Perspective	Easily
	Definition	Demand
	Broad	Fund
	Activity	Balancing
	Aspect	Practical
	Various	Establish
	Domain	Treat
	Certification	Qualitative
	Complex	Belief

Target Word	FFRDC Type Similarity Word
Effective	Known
	Walk
	Tension
	Beyond
	Correct
	Unless
	Challenging
	Fair
	Becoming
	Ad

The first model consisted of searching target words related to effectiveness in the government type of organizations. In this particular case, it is being observed that systems engineering is effective in the sense that it provides the knowledge and comprehend to see interfaces among technologies. Interviewees in this type of organization consider effective individual someone who not only understands the system lifecycle but also possesses soft skills that assist him to deliver the intended product or service. Also, it could be seen how the position of systems engineers is observed through the lens of their peers. In the excerpt included the participant relied on the systems engineer, however this occurs after the experiment was conducted.

Anonymized examples of how participants relate to "effectiveness" in government organizations include:

- *"Right, so system **integration** is a huge part of something that a systems engineer could bring to the table, but we're not building those systems so I kind of can't fault them for not having the* *experience, but they have a general understanding of how this widget goes to this widget when you throw it inside of a flying can in the air."*

- *"Understanding how, not just at a high level how the system works but, in our **perspective** on the technology we're interested in, how all the technologies interlink together to develop a capability."*
- *"…Like being able to consistently deliver in a wide variety of environments I think, says a lot about somebody's effectiveness. So I think I'm good with that **definition**."*
- *"Somebody who knows what has to be done - what process, **activity** has to be done - but also understands the human side of it and being able to bring the other person to the right direction and keep the person motivated.*
- *"To me, systems engineering is a process or **activity** that involves bringing together multidisciplinary skills in order to accomplish an objective: which could be delivery of a service, it could be solving a problem, it could be just sharing information. But there is some objective in mind that's defined by a stakeholder or customer.*
- *"If I can manage it in-house, I'll try to do it in-house. If it's too overwhelming or it's just too **complex**, then I'm willing to listen to what the systems engineering folks have to say."*

With respect to the industry organization types, anonymized examples of how the word "effectiveness" was used by participants include:

- *"So when I took the more recent training, it **helped** things click a bit more. So that's probably the point there."*
- *"So a lot of times when I've started mentoring somebody, they'll ask a question that I just have either assumed I knew, or had never even though of; and if I don't know something I like to go find out the answer. So it's also **helped** me understand the business better when I get a question out of the blue that I don't know."*
- *"So sometimes tools can burn you as a system engineer or lack of tools or the way we manage them. I think that's the **easily** identifiable issue for leadership to try to resolve and then new tools come in."*
- *"The documents have value in that they communicate results of your thinking, and big projects **demand** lots of communication."*
- *"I think one of the enemies of systems engineering is silos and departments thinking that this is there responsibility alone. And from a project point of view, we **fund** departments to do a certain job and you really need to blur those lines between departments and pull in the team that you really need to think broadly. So I think that is a barrier when we start thinking along the lines of our departments and I have budget dedicated to my department to do this, so I don't need any other departments. You know, that's silo thinking."*
- ***"Balancing** competing interests, competing characteristics or facets. Whether that be technical only, which is what a lot of people think systems engineering is, or technical plus the other things like technical and business competitive, whatever you want to call it, characteristics that allow the product to be successful."*

The word embedding model for industry organizations reflects that effectiveness is related to mentoring and training as mechanisms that support systems engineer's effectiveness. Similarly, to government organizations, industry systems engineers are coordinators or mediators among multiple parties. Therefore, soft skills, in particular proper communication, is necessary as to serve as an effective system engineer.

With respect to the FFRDC organization types, the word effective was used as target word. This is due to the limited available data form this type of organizations. Effectiveness was not found in the corpus, thus the team searched for the term "effective". A few anonymized examples of how the word effective was used by participants in the FFRDC organizations include:

- *"I would say that there is nothing fundamentally wrong with the systems engineers. I know there are some people, I've* ***known*** *them for years, they've really got this arrogant attitude and they really think (org name) is a completely different animal. And they're not, they really aren't. It's the whole thing, the environment, and the type of work we do and it's really mostly the environment. The way the company treats people, but other companies have good people, they're the same people that come right out of school, they go in one direction, they go to (org name) or they go there. I don't think there's anything wrong with the people."*
- *"But that's actually sometimes the advantage that I think we have as an FFRDC and as systems engineers a lot of times is we can, I mean there's artful ways of doing it but we have the ability to communicate sometimes the news that they don't necessarily want to hear but they need to hear. There's artful ways of doing that and sometimes you have to do it multiple times until they finally get it but after you try a certain number of times there are going to be times where you're like you know what these guys are never going to get it and that's when you've got to* ***walk*** *away.*
- *"And even though we're doing research sometimes by the time we get the funding for the research the research has already been done in other places, so it's a* ***challenging*** *environment to be in."*
- *"And you know we're like, and the* ***tension*** *is internal too, I mean sometimes we feel like even internally as a systems engineer you say isn't there a way to shortcut some of this so that we can get, can be more responsive? So that* ***tension*** *is always there."*
- *"And the organization also provides lots of opportunities for sharing* ***beyond*** *the department meetings, technical exchange meetings."*
- ***"Correct****, so everybody's an expert in something so they want to be a mentor in that, rather than recognize that they could be the student in another dimension.*
- *"And I also saw that continuous learning was highly recommended. It was pretty much, you are going to do this. You are not going to be successful* ***unless*** *you have continuous learning."*
- *"If you're a systems engineer you understand that value of having people share information at that level and in a very consistent way too, we hold a* ***fair*** *number of these meetings and they're voluntary because people have direct work but I think the fact that our attendance is pretty large with these meetings says that the employees value it too."*

From such excerpts, it can be observed that proper communication and coordination is essential for effective systems engineers. Similar with other organization types mentoring is seen as a key tool to continue growing professionally. On the other hand, the environment in which the systems engineer operates is seen as the factor that hinders effectiveness. Such statement triggers new questions that could be exploring including:

- What characteristics of an organization influence and hinder the performance of systems engineers?
- To what extent does organizational culture alter the effectiveness of systems engineers?

In essence, the analysis of effectiveness by organization type indicates that in all three categories mentoring, training and appropriate communication supports and characterizes effective systems engineers. For government organizations a systems engineer is the individual who leverages technical and personal resources to provide value. In industry organizations a systems engineer is a person who coordinates stakeholders, while in FFRC a systems engineers serves as a mentor and coordinator.

Once the team understood how the term effective was used in the corpus. The next target word was "culture" aiming to infer similarities and differences in culture among the three organization types. Table 8 shows the 10 most similar words according to the respective organization type.

Table 8. Top 10 similar words to culture in the government, industry, and FFRDC organizations types.

Target Word	Government Type Similarity Word	Industry Type Similarity Word	FFRDC Type Similarity Word
Culture	Reason	Extent	Got
	Wanted	honest	Job
	Individual	Ethic	Role
	Fire	Struggle	People
	Equipment	Passion	Think
	Seeing	Interest	Know
	Happened	Measured	Kind
	Soldiers	Helpful	Year
	Result	Talent	Different
	Effort	Bias	Project

With respect to the government organization types, anonymized examples of how the word "culture" was used by participants include:

- *"I think there's a multitude of **reasons**, I think it's general ambiguity as we said before about the value that this organization brings as a whole. People are very hesitant to actually seek out help from anybody over here. And that's based on reputation, it's based on word of mouth. So a bunch of things.*

- *"Part of the **reason** why it's so confusing for systems engineers is because the individual groups in systems engineering fight with each other all the time.*

- *"I mean we didn't build it because they **wanted** it, we built it because there's a requirement to deploy cheaper, inexpensive targets.*

- *"But keep in mind when you make the statement value to the customer, in my mind, and we deal with it all the time, the customer really doesn't care about the organization constraints that the **individual** systems engineer is coming from, all they care about is they're getting value to them.*

- *"In the real world there's industry where people get fired if you don't show up to work on time. Where if you don't do this job to my satisfaction, the guy who takes your place, he'll do it… They don't have to worry too much about being **fired** once they've been in a couple, three [years]. Now they may not ever get promoted or it may be relegated to, but it's really tough to fire a federal employee and you know, ever since Andrew Jackson's time.*

- *"You've got **equipment** on the range that is…50 years old. It's still there. You've got protocols that were established back in the 70's and 80's when the range had a lot of activity and nobody bothered to change them because they were working, or worked, so don't change it."*

- *"We also got into a spiral over the last ten years where it became a culture of get it out there, get it out fast because the **soldiers** need it.*

The analysis of culture illustrates the challenges the systems engineers face. For instance, constant fighting with other systems engineering groups, the particular characteristic of federal jobs where the employees do not have to worry about being fired, relying rigid and structured processes developed in the 70's and 80's, etc. Thus, it can be observed that systems engineers are highly influenced by the cultural characteristics of the government organizations.

The target word culture in industry type organizations shows that this type of institutions offers more flexibility to the systems engineers as new generation of individuals join the organization. In contrast to government entities, the example excerpts do not express negative sentiment towards the organization. It is recognized that there are challenges that still need to be addressed and there is bias toward the high seniority levels but there is a positive attitude towards the organization type. Examples of how the word "culture" was used by participants include:

- *"But that said, it takes a while even in formal mentoring for it to be really mentoring. To some **extent**, you're always advertising here - to some extent you don't want them to think that you have a bad attitude or that you are really stupid asking something."*

- *"I think to be **honest** it's a blend here. We're not viewed as ideal fixed system structured organization; there are individuals not only in software, I see them in hardware teams, that you can say have a system mindset and they're applying the system approach and our team depends on those individuals a lot."*

- *"There seems to be more movement by the younger generations than by people from my generation. I think that's just the way of the world. Just the whole work **ethic**, the loyalty aspect, has been changing over the last 5-10 years. Have I seen it? Yes, but I don't have any statistics."*

- *"We even **struggle** hiring people with experience to come in and do it here. So much of it requires understanding the product, understanding the organization. Knowing who to go see, how the process works and so on. I think people who come in and try to go straight into those roles, it's not saying that nobody can but it's tough if you're coming in green."*

- *"So far what I've seen, and this is speaking back into the past a little bit, you usually have one established discipline and, you're right, at some point maybe you're software, maybe you're hardware. More so software these days, seem to be getting a few more people from software into systems, sometimes by invitation, sometimes by expressing **interest**. As far as youngsters coming up, I think we're more conscientious about that now."*

- *"I think a lot of the people you see are the most experienced people, maybe people that have been around a while, different areas so I think there's definitely a* ***bias*** *towards more experienced engineers."*

With respect to the FFRDC organization types, examples of how the word "culture" was used by participants include:

- *"Mentoring is clearly important, they've* ***got*** *… formal and informal mentoring program where staff volunteer to be mentors. I think it's a minority of staff are mentors and those who do are very good and I think a minority of the staff take advantage of the mentoring program."*
- *"And the way it is executed is generally with the first line supervisor and the project lead of the cognizant domain. So the project lead in all cases will look at the staff and bring the staff into certain niches and orient them to the project through on the* ***job*** *experience, small chunks of work and then ultimately larger exposure to the problem."*
- *"In this industry we often switch* ***roles*** *back and forth, sometimes we're doing the work as an engineer, sometimes we're doing the work as a project leader. Sometimes we're doing it as an operational leader and a business and I've done all of those."*
- *"Sometimes I don't like saying systems engineering because it pushes* ***people*** *into the waterfall lifecycle kind of thinking, and that happens here too."*
- *"Every* ***year*** *we ask for ideas from anybody in an idea market, and so ideas can be generated out and then, so that kind of gives us a basic discussion, a high level discussion in the corporation about research, routinely."*
- *"Some domains do have a very aggressive process in place to educate their staff, get them to learn, they have people come in and talk and they'll have these seminars. The majority of divisions could care less, they're very* ***project*** *focused, as long as the project is getting the job done, the customer is happy, they're happy. And you can live in that world for your whole, for ten years."*

Form the excerpts, it can be observed that a culture of mentoring and exchanged of ideas is embedded in FFRDC. Also, systems engineering seems to have a processes-oriented reputation that may be counterproductive for collaboration. Lastly, similar to industry and contrary to government entities, FFRDC culture is observed as positive as the interviewees suggest areas of opportunity but does not describe their culture as a factor that hinders their effectiveness.

In summary, culture related excerpts indicate that the culture of government organizations offers more challenges to systems engineers as they constantly fighting with other systems engineering groups. Other factors such as job security and relatively old processes have impact on the effectiveness of systems engineers. In contrast, industry offers more flexibility as new hires join the organizations bringing with them new perspective, while FFRDC promotes mentoring and collaboration as its basis.

4.2.3 Summary from Data Modeling and Visualization

The results generated from the proposed methodology for text analysis on interview transcripts helped to identify the topics discussed in the dataset and the words associated with each topic.

It also shows the most frequent words identified in the dataset and their correlations. These results determine the cultural or organizational difference between organization types based on their definitions of topics that are illustrated in the results section. The Helix team is currently exploring further detailed analysis by analyzing which words should be considered as a "stop-word", as well as the study of n-grams within the text. Further analysis of the visualizations should be considered if a stop-word is added to the original list or if the words are to be considered as n-grams. The analysis by domain such as defense, healthcare, transportation and so on is in process.

The visuals presented in this work will help organizations realize their strengths, weaknesses and the set of skills systems engineers should have to fulfill an organization's requirement. Moreover, the visuals will facilitate the identification of qualities of an effective systems engineer, which will complement an organization's culture, as every organization has a different culture according to their business requirements. In addition, these visualizations will be used along with qualitative techniques to find out relationships between words, such as "work" and "project", and how those words are being used within the system engineers' language.

4.3 Relationships from the Dataset

The ultimate goal is for all of the analyses highlighted above to help the Helix team identify critical relationships that will feed an organizational simulation to support exploration and improvement of organizational effectiveness. (See Section 6) To do this, patterns in each variable and the relationships between patterns in this data must be carefully examined. One hypothesis, highlighted above, is that agile and rapid approaches may be better supported by the Adhocracy archetype in the CVF than the Hierarchical archetype and, conversely, the Hierarchical archetype may be best suited to rigorous acquisition-focused systems engineering processes. In order to understand this, the CVF data has to be analyzed to identify the patterns in cultural archetype; the processes described paired with data on the effectiveness of those processes; and that data compared with overall assessments of the effectiveness of systems engineering in the organization. Then, these intra-organizational patterns have to be compared between organizations.

The current dataset does not have enough diversity of organizations to complete this analysis at the time of this report. Additional organizations have been recruited and should be participating in the survey in spring 2019. Once this additional data is collected and analyzed, more detailed patterns can be identified.

4.4 *Atlas* Update

One of the tasks for the Helix team in 2018 was to determine whether additional updates to *Atlas* were required. Analyses are ongoing, but no data collected to date from the survey or through over 100 additional interviews conducted indicate a need to change *Atlas* at this time.

4.5 Systems Engineering Capability

***Capability** is defined as the ability to achieve a desired effect under specified (performance) standards and conditions through combinations of ways and means (activities and resources) to perform a set of activities. (DoD, 2009)*

The term capability is commonly used in operational and acquisition contexts within the defense community. In a broader context, the definition of capability is asserted as the ability to do something, and capability engineering is the "overarching approach that links values, purpose, and solution of a systems problem" (Henshaw et al., 2014). Using a soft systems methodological approach, the INCOSE UK working group identified eight perspectives of capability and capability engineering (Henshaw et al., 2014). In the 2018 INCOSE Systems Engineering Competency Framework, one of the new framework competency areas included capability engineering as one of the core systems engineering principles (INCOSE, 2018).

Based on the adaptation of various literature definitions of capability, systems engineering capability is defined in terms of people (competencies), processes, and equipment, the integration of which leads towards the ability to perform systems engineering activities to produce an engineered product or service. It is worth noting that "competence" differs from "capability". Capability is an organizational or organizational team attribute that refers to the ability to execute the mission of the organization (INCOSE, 2018). The Helix team conducted a literature review of systems engineering capability and built on this work to develop clear methods for understanding and assessing how systems engineers are supported or impeded in providing an effective systems engineering capability.

In all the interviews, the Helix team probed the concept of value. There are two general forms of value from the interview discussions: (1) an individual's perspective on the primary value that they provide as a systems engineer, and (2) an individual's perspective of the overarching value that the community of systems engineers in their organization provide. Most systems engineers defined value in terms of the overall project success with respect to the "iron triangle". The "iron triangle" is a well-known metaphor based on the fact that those three dimensions of a project compels its success. Although there are numerous adaptations of the "iron triangle", the two corners of the triangle are *time* and *cost* (or synonyms for those terms). The third corner may vary but is usually *requirements, scope, quality, or capability* (Pyster et al., 2018).

The Systems Engineering Book of Knowledge (SEBoK) has identified the need for determining the required systems engineering capabilities in businesses and enterprises (BKCASE Editorial Board, 2017). The systems engineering capabilities support the systems engineering organizational strategy and the following are essential steps that can help an organization determine its desired systems engineering capabilities (BKCASE Editorial Board, 2017):

1. Understand the context
2. Determine the required systems engineering roles
3. Determine the competencies and capabilities needed for each systems engineering roles
4. Assess the ability and availability of the needed systems engineering organizations, teams, and individuals

5. Make adjustments to the required systems engineering roles based on the ability and availability
6. Organize the systems engineering function to facilitate communication, coordination, and performance

In 2008, Andres and Peterson presented on systems engineering capability development highlighting the notion that increased complexity in systems demands increased systems engineering capability. Traditional systems engineering approaches are insufficient for the growing large-scale complex systems. Key considerations for increased systems engineering capabilities are as follows (Andres and Peterson, 2008):

- Agile and lean processes for rapid development
- Integration of advanced technologies across multiple systems of systems
- Increased demands requiring optimal trades or balancing, and
- System of systems analysis and interoperability among these systems

One important step to success is for an organization to benchmark their own systems engineering capability, identify gaps, and plan for improvements (Andres and Peterson, 2008). The following are strategies outlined by Andres and Peterson to building systems engineering capability (Andres and Peterson, 2008):

- Define and document the requirements
    - Conduct quality function deployment (QFD) sessions to gather the voice of the customers (VOC)
    - Benchmark other systems engineering organization or efforts
    - Leverage DoD, industry or academia research studies
- Baseline capabilities
    - Establish a baseline of systems engineering capabilities and performance
    - Identify areas for improvement and make the business case for proposed changes based on the possible risks and opportunities
- Develop a capability development plan
    - Build a focused and prioritized work plan to address the gaps identified within the organization
    - Leverage strengths and best practices from industry
    - Institutionalize systems engineering

5: Conclusions

Because data collection and analysis is ongoing, the team does not wish to overstate current findings as final conclusions. However, there are a few items worth noting. For example, preliminarily, the team is starting to see patterns between the CVF profile of an organization and the Qi Index profile. There is not a one-to-one correlation, but for example, organizations that are primarily “Clan” focused (CVF) in the data also show relatively strong generative characteristics. However, the team needs additional diversity in the sample to determine when or if similar characteristics could hold in other types of profiles. For example, under what conditions could a strong Hierarchy culture also show a “generative” profile? Or are there certain types of systems engineering (for example, the most common process-focused, acquisition approaches) that can be effective in organizations without a generative profile? The Helix team is continuing to explore these questions.

The team has gained agreement from 3 additional organizations to participate in the survey as well as from INCOSE to encourage its members to participate in the survey as “at large” participants. There are also several organizations currently considering participation in the Helix survey. The team is intentionally seeking organizations that are likely to improve the diversity of the dataset, helping to illuminate these types of findings. Continued mining of the interview data will also help to enrich the team’s understanding of the variables highlighted in *Atlas*^{ORG} (Figure 2) and their interrelationships.

As of the publication of this report, the team has accomplished the following:

- Systematically collected and analyzed interview data from **29 organizations**, a group of consultants, and **464 participants**, including systems engineers and those who work with systems engineers.
- Published nine (9) technical reports.
- Determined that no updates to *Atlas* are necessary based on the current year findings.
- Made numerous presentations to such groups as the SE Forum, National Defense Industrial Association (NDIA) SE Division (SED), and the International Council on Systems Engineering’s (INCOSE) Corporate Advisory Board, published ten conference papers, delivered several more conference presentations, and submitted additional papers for review and possible publication.
- Worked with several early adopters as they implemented aspects of *Atlas* in their organizations.
- Identified more potential *Atlas* adopters.
- Updated the interview approach and questions for organizational site visits and interview sessions. (See Appendices C-F)
- Launched two surveys, which examine the cultures of organizations (using an existing model, the Competing Values Framework), how teams work within an organization (using an existing model, the Qi Index), and how systems engineering and systems engineers are viewed and perform in that organizational context. The surveys are focused on different types of participants: systems engineers themselves or their leadership, management, or peers.

- Created web-based tools to aide data collection and workforce development.
- Created a web portal to increase community visibility into research findings, provide easy access to the tools and surveys developed, and increase the dissemination of Helix materials.
- Created the infrastructure for data mining and conducted data mining on the existing dataset, adding new data as it was collected.
- Based on the data mining, created visualizations that serve as an early reference model for future work.

In addition, Helix researchers Pyster, Hutchison, and Henry, have published a book based on the Helix project findings, *The Paradoxical Mindset of Systems Engineers: Uncommon Minds, Skills, and Careers*. Finally, Hutchison, Pyster, and Henry published a chapter entitled, “From “T” to “Π”: The Other Leg That Systems Engineers Stand On” in *T-Shaped Professionals: Adaptive Innovators*.

The data collection and analysis are ongoing, and the team plans additional work as outlined in Section 6.

6: FUTURE RESEARCH DIRECTIONS

The Helix team plans to expand upon the research developed during the execution of earlier research tasks supporting the Helix project. There are six specific areas the Helix team must continue to investigate:

1. Advance experimentation, data collection and analysis focused on:
    a. systems engineers, focusing on synergies created when assessing teams or the systems engineering workforce holistically.
    b. organizational characteristics that support or inhibit systems engineers' ability to deliver an effective systems engineering capability.
    c. organizational methods use to improve their systems engineers' ability to deliver effective systems engineering capabilities, and their efficacy.
2. Advance data analysis capabilities, including implementing natural language processing techniques and statistical methods to analyze interview transcripts, resumes, survey data, and organizational profiles searching for patterns and trends in systems engineering effectiveness.
3. Develop models that support the exploration of and relationships between the above variables.
4. Use the above models to build decision support tools that organizations could use to assess and explore the effectiveness of their systems engineering workforce and systems engineering capability.
5. Conduct a workshop with subject matter experts to review the models and tools, collect user data and feedback, and use these to refine the final tools.
6. Develop a mechanism to transition Helix from an OSD-funded research project to a community-adopted set of tools and resources.

The evolution of Helix research from a focus on the individual systems engineer to the success of an overall engineering organization will require the adoption of a more advanced set of tools. In the past, Helix has primarily relied upon surveys and documented information as a means of assessment. However, the complexity of understanding individual, team and organization dynamics will require a new set of tools to objectively come to an understanding of the impact of the elements of interest. As noted in the Cynefin Framework, complicated systems can be understood through the collection of data and analysis, whereas complex systems require experimentation, as the relationships between cause and effect are often unclear. (Dettmer, 2011)

There are two critical end goals for Helix in 2019. The first is to transition the project from centrally-funded research to a community-led and maintained activity. This includes increasing the adoption and use of *Atlas*. The team is continuing to work with organizations that have used Helix and is working with additional organizations that have expressed interest in using Helix. In addition, the Helix team is scheduling meetings with key professional societies to determine their interest in helping to govern and maintain Helix going forward. The goal is to create a set of community resources that can be implemented independently of the Helix team and a platform that allows sharing across the community as they implement these resources and identify areas for growth and improvement. The Helix team hopes that some mechanism for exploring the dataset – the most comprehensive dataset on systems engineering workforce and effectiveness that the team is aware of – will be part of this effort. IRB protocols do not allow for full sharing of raw data, but it is possible that some interfaces can be created to allow exploration of patterns in the data without making the raw data publicly available. Finding a resolution for this – or determining that it is not possible within the data protection protocols – will be concluded in 2019.

The second major goal for the 2019 work is to create the simulation environment that will allow organizations to explore their systems engineering capabilities. Notionally, this will enable organizations to explore each of the variables highlighted in the methodology and results (illustrated in Figure 2), get an overall assessment of their current systems engineering capability, and using the simulator explore how certain changes in the organization may impact their systems engineering capability. The team also would like to include some basic indicators of the difficulty of these changes. For example, increasing workforce proficiency in an area such as "modeling" may be relatively straightforward while driving a major shift in culture may take years, vast resources, and a complete change in how decisions are made within the organization. This is not impossible – but organizations should be aware of the challenges in and benefits of these types of changes. A very notional example of this is illustrated in Figure 27 below.

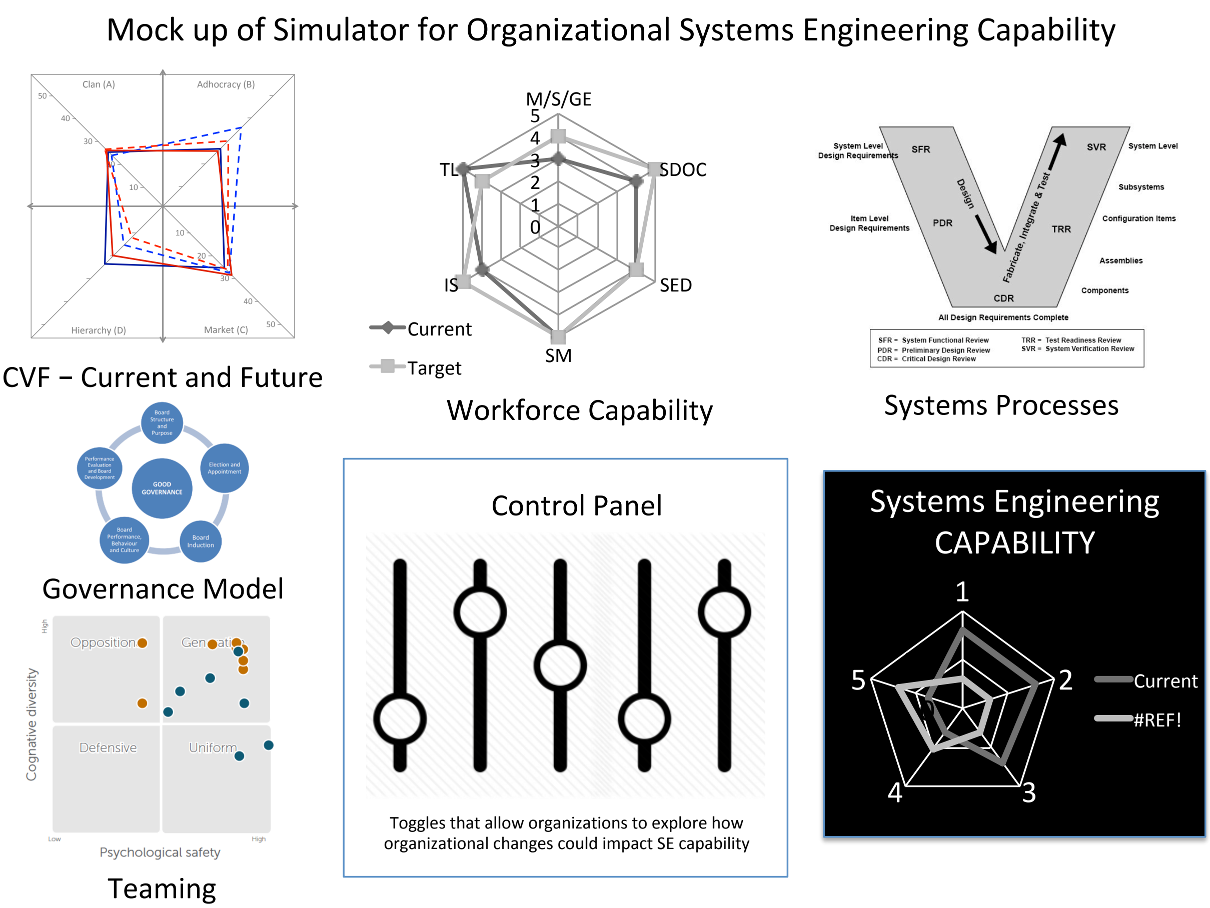

Figure 27. Mock-Up of Organizational Simulator

One of the critical decisions for the simulator will be how to enable users to interface with it. In particular, must organizations collect detailed information on culture, governance, workforce, etc. – in other words, conducts a mini Helix project – in order to use it? Or can there be options that simply allow exploration based on senior leaders' understanding of their organization based on the overall dataset. Likely, both approaches have a place in the community, but the team must decide on the appropriate path(s) soon.

The Helix team plans to coordinate with the Netherlands companies that participated through a workshop in the April timeframe. An additional workshop has been proposed around the INCOSE International Symposium. The purpose of this workshop will be to gather feedback from potential users and improve overall community outreach. The workshop will also be an opportunity to recruit additional organizations interested in implementing Atlas.

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Appendix A: Web-Based Tool for Assessing Proficiency

This appendix provides additional guidance for individuals using the web-based self-assessment tools available on the helix website (http://helix-se.org). Proficiency defines the knowledge, skills, abilities, behaviors, patterns of thinking, and abilities that are critical to the effectiveness of systems engineers. The *Atlas* proficiency model consists of six difference proficiency areas:

- Math/Science/General Engineering: Foundational concepts from mathematics, physical sciences, and general engineering;
- System's Domain & Operational Context: Relevant domains, disciplines, and technologies for a given system and its operation;
- Systems Engineering Discipline: Foundation of systems science and systems engineering knowledge;
- Systems Engineering Mindset: Skills, behaviors, and cognition associated with being a systems engineer;
- Interpersonal Skills: Skills and behaviors associated with the ability to work effectively in a team environment and to coordinate across the problem domain and solution domain; and
- Technical Leadership: Skills and behaviors associated with the ability to guide a diverse team of experts toward a specific technical goal.

Each of these areas contains several categories, or groupings of related knowledge, skills, abilities, behaviors, or cognitions, as illustrated in Table 1.

<u>Self-Assessment</u>

In order to perform a self-assessment, individuals are asked to review the definitions of the proficiency areas above and the categories in Table 1. Additional detail can be found in the full report on *Atlas 1.1*, found at the Helix webpage (http://www.sercuarc.org/projects/helix/). Then use the template to generate a "0 to 10" initial assessment of your current proficiency in each Area, with "0" meaning you have no skill in the area and 10 meaning your skills are the top within your experiences. Consider the following guidelines:

- For each Proficiency Area, think about proficiency across *all categories*, not just one. For example, if you are a "10" in a single category, but a "5" in all others, you would not be a "10" for the entire Area.
- For each Area, think about what is most critical for your current position. This may not change your assessment, but may mean that a lower number not an issue.
- Consider your past experiences in the Area, any training or education that might be relevant, and where you might have received guidance from a mentor or leader. These things together will have shaped your proficiency, and thinking about them may help you to assess yourself more realistically.
- You know your strengths and areas for growth – be honest in your responses.

A proficiency rubric for further guidance can be found on page 78.

Once you have completed your initial assessment for your *current* proficiency, you can choose to retroactively assess what your proficiency was at different points in your career. For example, when you completed your undergraduate education or joined your current organization. This may help you to better reflect on changes over time. If you do this, revisit your current proficiency assessment afterwards and determine whether any adjustments are required.

As discussed in the *Implementation Guide*, you should first review and tailor the rubric as appropriate for your position.

Atlas Self-Assessment Rubric

The following is the self-assessment rubric provided by *Atlas*. As with the proficiency model itself, you should review and tailor this as appropriate.

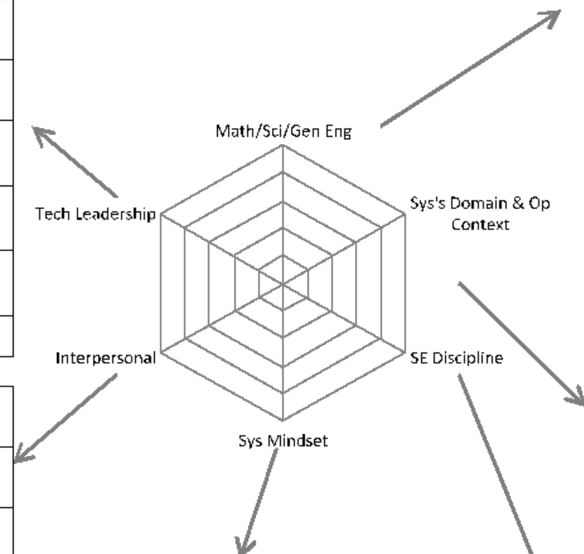
#	Level	Level Description
1	Fundamental Awareness	Individual has common knowledge or an understanding of basic techniques and concepts. Focus is on learning rather than doing.
2	Novice	Individual has the level of experience gained in a classroom or as a trainee on-the-job. Individual can discuss terminology, concepts, principles, and issues related to this proficiency, and use the full range of reference and resource materials in this proficiency. Individual routinely need help performing tasks that rely on this proficiency.
3	Intermediate	Individual can successfully complete tasks relying on this proficiency. Help from an expert may be required from time to time, but the task is usually performed independently. The individual has applied this proficiency to situations occasionally while needing minimal guidance to perform it successfully. Individual understands and can discuss the application and implications of changes in tasks relying on the proficiency.
4	Advanced	Individual can perform the actions associated with this proficiency without assistance. The individual has consistently provided practical and relevant ideas and perspectives on ways to improve the proficiency and its application and can coach others on this proficiency by translating complex nuances related to it into easy to understand terms. Individual participates in senior level discussions regarding this proficiency and assists in the development of reference and resource materials in this proficiency.
5	Expert	Individual is known as an expert in this proficiency and provides guidance and troubleshooting and answers questions related to this proficiency and the roles where the proficiency is used. Focus is strategic. Individual have demonstrated consistent excellence in applying this proficiency across multiple projects and/or organizations. Individual can explain this proficiency to others in a commanding fashion, both inside and outside their organization.

This page provides the paper based self-assessment tool for *Atlas* proficiency. While the interactive tooling enables a deeper exploration by users, the paper version is very useful during facilitated discussions.

Date or Position: ______________________

Building and Orchestrating a Diverse Team	
Balanced Decision Making & Rational Risk Taking	
Guiding Diverse Stakeholders	
Conflict Resolution & Barrier Breaking	
Business and PM Skills	
Establishing Technical Strategies	
Enabling Broad Portfolio-Level Outcomes	
Self-Assessment	

Natural Science Foundations	
Engineering Fundamentals	
Probability and Statistics	
Calculus and Analytical Geometry	
Computing Fundamentals	
Self-Assessment	



Principal and Relevant Systems	
Familiarity with System's Concept of Operations	
Relevant Domains	
Relevant Technologies	
Relevant Disciplines and Specialties	
System Characteristics	
Self-Assessment	

Communications	
Listening and Comprehension	
Working in a Team	
Influence, Persuasion, and Negotiation	
Building a Social Network	
Self-Assessment	

Big Picture Thinking	
Paradoxical Mindset	
Adaptability	
Abstraction	
Foresight and Vision	
Self-Assessment	

Lifecycle	
Systems Engineering Management	
SE Methods, Processes, and Tools	
Systems Engineering Trends	
Self-Assessment	

An individual's career path is the precise combination of experiences, mentoring, education, and training that an individual goes, particularly their characteristics, timing, and order. In order to complete a career assessment, an individual should work through the steps outlined here while filling out the career path template.

Experiences

The Helix team chose to use a position as the unit of measure for experiences; a position is established by the organization and defines the roles and responsibilities to be performed.

Based on both the literature and the Helix data itself, each position has several characteristics:

- Relevance: A 'relevant' position is one that enables a systems engineer to develop the proficiencies critical to systems engineering. Determine a starting point for relevant experiences; this will become the first position (P1) of the career path. Fill in the title and the year(s) for the position(s).
- Organizations: Fill out the name of the organization for each position. This will help to show any transition or variation between organizations.
- Roles: A role is a collection of related systems engineering activities. Roles were identified based on the activities consistently performed by systems engineers. There are 16 roles identified in *Atlas*, as described in Table 1, below. For each position, review your activities and responsibilities and write down *all* roles played during that position.
- Lifecycle Phases: Generic systems engineering lifecycle phases considered in *Atlas* are based on the lifecycle phases in the *Guide to the Systems Engineering Body of Knowledge (SEBoK*), as explained on page 5. (BKCASE Authors 2016) For each position, fill in the area(s) of the lifecycle you worked on.
- Key Milestones. Note any key changes in types of positions under key milestones. For example, first systems engineering role, first chief systems engineer role, first supervisory position, etc. would all be indicators of change or growth over career.

Education and Training

Note any educational milestones or key training milestones with the position/timeline in which they occurred. Education milestones may include the completion of a degree or participation in a course that was particularly relevant or impactful for your career. Key training is training that was particularly impactful or useful for your career. You do not need to include training that did not have an impact.

Other

Your organization may ask you to add other information, such as participation in professional societies, publications, etc. to your career path.

Role Name	Roles Focused on the Systems Being Developed
Concept Creator	Individual who holistically explores the problem or opportunity space and develops the overarching vision for a system(s) that can address this space. A major gap pointed out to the Helix team – particularly when working to implement the findings of Helix – has been that of the development of an overarching system vision. This is a critical first step in the systems lifecycle, and several organizations stated that they believed it needed to be separately called out. In addition, when looking to the future of what systems engineers need to do (e.g., INCOSE Vision 2025 (2015)), the focus on early engagement and setting the vision was deemed critical.
Requirements Owner	Individual who is responsible for translating customer requirements to system or sub-system requirements. This is updated from *Atlas 1.0*. Sheard (1996) also included the activities around functional architecture in this role. However, in working with the community, this has caused some confusion as to the differences between this role and that of "System Architect". The Helix team believes that grouping all architecture activities together will improve clarity on the roles.
System Architect	Individual who owns or is responsible for the architectures of the system; this including functional and physical architectures. This is updated from *Atlas* 1.0. This is an update of Sheard's "System Designer" role (1996). There was concern both at community events and during later interviews that nowhere in the presented framework did the critical role of systems engineers in architecture come out clearly. Some also argued that "Design" gave the impression that this role focuses specifically on the details of systems design over architecture.
System Integrator	Individual who provides a holistic perspective of the system; this may be the 'technical conscience' or 'seeker of issues that fall in the cracks' – particularly, someone who is concerned with interfaces. Likewise, there was concern over the word "Glue", which many expressed was not clearly descriptive enough.
System Analyst	Individual who provides modeling or analysis support to system development activities, and helps to ensure that the system as designed meets he specification. This is unchanged from Sheard's roles (1996).
Detailed Designer	Individual who provides technical designs that match the system architecture; an individual contributor in any engineering discipline who provides part of the design for the overall system. This is an addition based on the Helix data. While systems engineers do not always get involved with detailed design, in smaller organizations or on smaller projects it is more common. Likewise, systems engineers who had played this role explained that it was critical in developing their own technical and domain expertise as well as in understanding the design approaches of classic engineers.
V&V Engineer	Individual who plans, conducts, or oversees verification and validation activities such as testing, demonstration, and simulation. This is unchanged from Sheard's roles (1996).
Support Engineer	Individual who performs the 'back end' of the systems lifecycle, who may operate the system, provide support during operation, provide guidance on maintenance, or help with disposal. This was previously titled "Logistics and Operations Engineer" in Sheard (1996). However, in interviews and at community events, the Helix team received feedback that using this title gave

	the impression that this role was limited and did not encompass the full spectrum of systems engineers' activities at system deployment or post-deployment. Likewise, in several organizations, "logistics" and "operations" were seen as separate disciplines from systems engineering, which caused some contention in discussions. The renaming of this category is intended to address these issues.
Roles Focused on Process and Organization	
Systems Engineering Champion	Individual who promotes the value of systems engineering to individuals outside of the SE community – to project managers, other engineers, or management. This may happen at the strategic level or could involve looking for areas where systems activities can provide a direct or immediate benefit on existing projects. Sheard recommended that a role such as this, labeled in her work as "Systems Engineering Evangelist", be added in (2000).
Process Engineer	Individual who defines and maintains the systems engineering processes as a whole and who also likely has direct ties into the business. This individual provides critical guidance on how systems engineering should be conducted within an organization context. This is unchanged from Sheard's roles (1996).
Roles Focused on the Teams That Build Systems	
Customer Interface	Individual who coordinates with the customer, particularly for ensuring that the customer understands critical technical detail and that a customer's desires are, in turn, communicated to the technical team. This is unchanged from Sheard's roles (1996).
Technical Manager	Individual who controls cost, schedule, and resources for the *technical* aspects of a system; often someone who works in coordination with an overall project or program manager. This is unchanged from Sheard's roles (1996).
Information Manager	Individual who is responsible for the flow of information during system development activities. This includes the systems management activities of configuration management, data management, or metrics. This is unchanged from Sheard's roles (1996).
Coordinator	Individual who brings together and brings to agreement a broad set of individuals or groups who help to resolve systems related issues. This is a critical aspect of the management of teams. This is unchanged from Sheard's roles (1996).
Instructor/Teacher	Individual who provides or oversees critical instruction on the systems engineering discipline, practices, processes, etc. This can include the development or delivery of training curriculum as well as academic instruction of formal university courses related to systems engineering. While any discipline could conceivably have an instructor role, this denotes a focus on systems and is a critical component in the development of an effective systems engineering workforce. This is an addition to the Sheard roles (1996 and 2000).

Systems Engineering Lifecycle Stages:

- Concept Definition - A set of core technical activities of SE in which the problem space and the needs of the stakeholders are closely examined. This consists of analysis of the problem space, business or mission analysis, and the definition of stakeholder needs for required services within it.

- System Definition - A set of core technical activities of SE, including the activities that are completed primarily in the front-end portion of the system design. This consists of the definition of system requirements, the design of one or more logical and physical architectures, and analysis and selection between possible solution options.
- System Realization - The activities required to build a system, integrate disparate system elements, and ensure that a system both meets the needs of stakeholders and aligns with the requirements identified in the system definition stage. This includes integration, verification, and validation (IV&V).
- System Deployment and Use - A set of core technical activities of SE to ensure that the developed system is operationally acceptable and that the responsibility for the effective, efficient, and safe operations of the system is transferred to the owner. Considerations for deployment and use must be included throughout the system life cycle. Activities within this stage include deployment, operation, maintenance, and logistics.
- Product and Service Life Management - Deals with the overall life cycle planning and support of a system. The life of a product or service spans a considerably longer period of time than the time required to design and develop the system. This stage includes service life extension, updates, upgrades, and modernization, and disposal and retirement. The organizations in the current sample are primarily concentrated on new development, so this is a very under-represented aspect of the life cycle.
- In addition to these life cycle phases, the SEBoK includes orthogonal activities of systems engineers, Systems Engineering Management, defined as managing the resources and assets allocated to perform SE activities. Activities include planning, assessment and control, risk management, measurement, decision management, configuration management, information management, and quality management. These activities can occur at any point in the systems engineering lifecycle.

Atlas Career Path Self-Assessment Tool (Paper-Based)

The following page provides the paper based self-assessment tool for *Atlas* proficiency. While the interactive tooling enables a deeper exploration by users, the paper version is very useful during facilitated discussions.

Career Path Self-Assessment Tool

Date: ________________

Concept Definition										
System Definition										
System Realization										
System Deployment and Use										
Product and Service Life Management										
Systems Engineering Management										
Role(s) Performed										
Domain(s)										
System Characteristics										
Position										
Organization(s)										
Dates										
Milestones (Key positions, education, or training)										

Objectives:

- Examine the organizational characteristics that strongly support or detract from systems engineers' effectiveness;
- Understand how systems engineers view their work and ability to be effective; and
- Prepare systems engineers to take the survey.

Getting to Know You

IND01 How did you become a systems engineer?

Defining Systems Engineering in the Organization

GRP01 In your own words, what is systems engineering [or equivalent term]?

GRP02 What does systems engineering include in your organization?
What are the most common activities of systems engineers?
How does systems engineering really work here?

GRP03 How are most of the outputs of systems engineering used here?

GRP04 How effective is systems engineering in your organization? How do you know?

GRP05 How do systems engineers know they make a difference in the organization?
Do you know how they will be rewarded and recognized?
Do systems engineers know how they can get promoted?

GRP06 Do you believe the people you work with see the positive effect you are having on projects here? How do you know?

Exploring Organizational Characteristics

GRP07 If you were to define the culture of this organization, what are the 3-5 words you would use?

GRP08 If you could do or change one thing in your organization to make systems engineering more effective, what would it be?

GRP09 What did we not talk about that you would like to share with our team?

Time Permitting

ACT01 Draw a picture or a chart that shows how systems engineering is REALLY done here, in your experience.

Follow up: Thinking about the culture of the organization, what aspects of "the way we do things around here" contribute to SE growth and success and which hinder SE growth and success here?

ACT02 Thinking about your experience in this company, please tell me the first three words that come to your mind when I say each word:
Systems engineering
Systems engineering management
Senior management
[Company Name]

Appendix D: Group Discussion Questions – Executives and Senior Leadership

Objectives:

- Validate or modify current Helix understanding of the values provided by systems engineers;
- Examine organizational culture, governance, structure and impacts on effectiveness;
- Examine how systems engineering effectiveness is viewed within an organization; and
- Prepare participants to participate in the survey.

Getting to Know You and Your Organization

ESR01 Please introduce yourself, your role, and explain what relationship you have with systems engineering (if any).

ESR02 What 3-5 words would you use to describe the culture here?

Overview of Systems Engineering

ESR03 How do you define systems engineering [or equivalent term] here?

ESR04 Is systems engineering effective here? How do you know? Does your organization use any metrics for effectiveness (qualitative or quantitative)?

ESR05 Is your current level of investment in systems engineering [or equivalent term] worth it?

If the current investment is not appropriate, what should change?

ESR06 How would you define the return on investment for systems engineering here?

Integration of Systems Engineering in the Organization

ESR07 When negotiating budgets for Systems engineering work and for systems engineers, how do you communicate value to your peers and other decision makers?

(Give us an example of a pitch you made for systems engineering recently…)

ESR08 What tensions exist, if any, between systems engineering groups and other parts of the organization? For example, what conflicts get escalated to you?

ESR09 What tensions exist, if any, between systems engineering groups and other parts of the organization? For example, what conflicts get escalated to you?

ESR10 What are some examples of how leadership in the organization shows support for systems engineering?

Wrap Up

ESR12 Given where the senior leadership team is taking the company today, what advice do you have for systems engineers and their managers?

ESR11 If you could do or change one thing that would increase systems engineering effectiveness here, what would you do?

ESR12 What did we not talk about that you would like to share with our team?

Objective:

- Gather official organizational views on systems engineering roles, positions, career paths, advancement, etc.; and
- Gather additional data points on organizational culture outside of the systems engineering group.

Getting to Know You and Your Organization

HR01 Please introduce yourself, your role, and explain what relationship you have with systems engineering (if any).

HR02 What 3-5 words would you use to describe the culture here?

Organizational Positions on Systems Engineering

HR03 How are systems engineers [or appropriate title] identified and recruited here?

HR04 What is the organizational approach to training and developing systems engineers?
What is standard for all?
What is dependent on employee or manager choices?

HR05 Do you track any metrics that help you determine if this approach is effective?

HR06 How is systems engineering rewarded within the organization?
Does this differ from how other types of engineers are rewarded?

Wrap Up

HR07 If you could do or change one thing about the way the organization handles systems engineers from an HR perspective, what would you do?

HR08 What did we not talk about that you would like to share with our team?

Objectives:

- Validate or modify current Helix understanding of the values provided by systems engineers;
- Understand the overlap in views for systems engineers and non-systems engineers who have related professions; and
- Prepare peers and practitioners in related disciplines to take the survey.

Getting to Know You/the Organization

NSE01 Please introduce yourself and describe your primary roles and responsibilities.

NSE02 How would you describe the structure of your organization?

Is this organization very hierarchical? Fairly "flat" in terms of structure? Etc.

Overview of Systems Engineering/Overlap with Your Work

NSE02 From your perspective, what value does systems engineering provide to overall product design and development?

NSE03 Please describe the relationships between your [department, division, team] and the systems engineering [division, department, team].

How dependent upon the work of the systems engineering organization is your organization?

How dependent upon your organization is the SE organization? (I think maybe a more general question about the relationships makes sense.)

How does systems engineering impact (either negatively or positively) the ability for your organization to succeed in carrying out its charter?

How does your organization impact (negatively or positively) the ability for the SE organization to succeed in carrying out its charter?

NSE04 Do you feel like you understand the processes and approaches that systems engineers use here? If not, what is unclear? If so, can you describe this approach at the high level?

Organizational Culture

NSE04 How would you describe the culture of this organization?

What 3-5 words would you use to describe the culture here?

NSE05 How do aspects of this culture support or get in the way of good systems engineers? What are you doing that perpetuates the current culture - for good or bad?

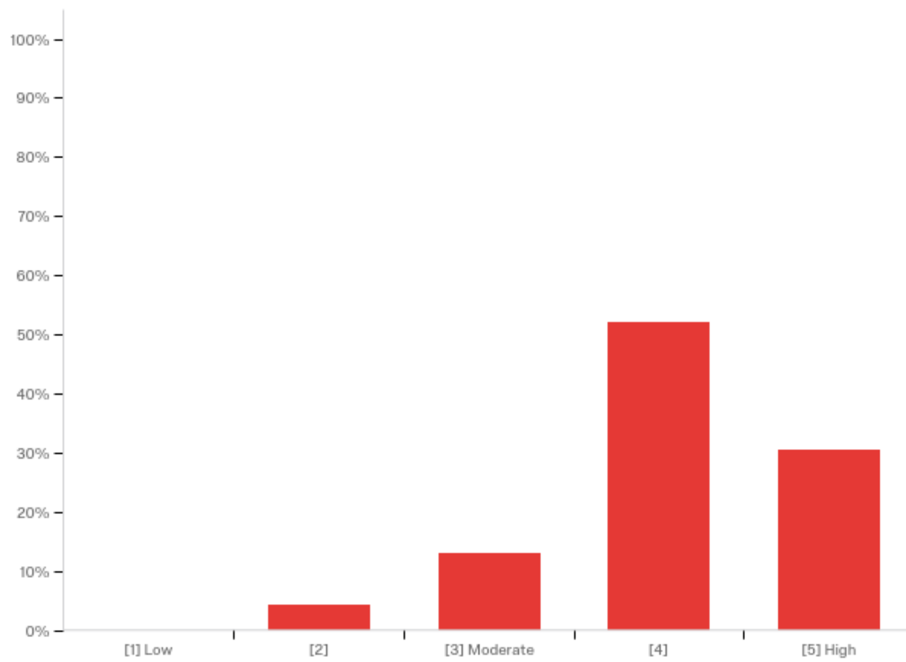
NSE06 Given where senior leadership team is taking the company today, what advice do you have for systems engineers and their managers?

NSE07 If you could do or change one thing in your organization to get systems engineering to provide the values you want, what would that be?

NSE08 What did we not talk about that you would like to share with our team?

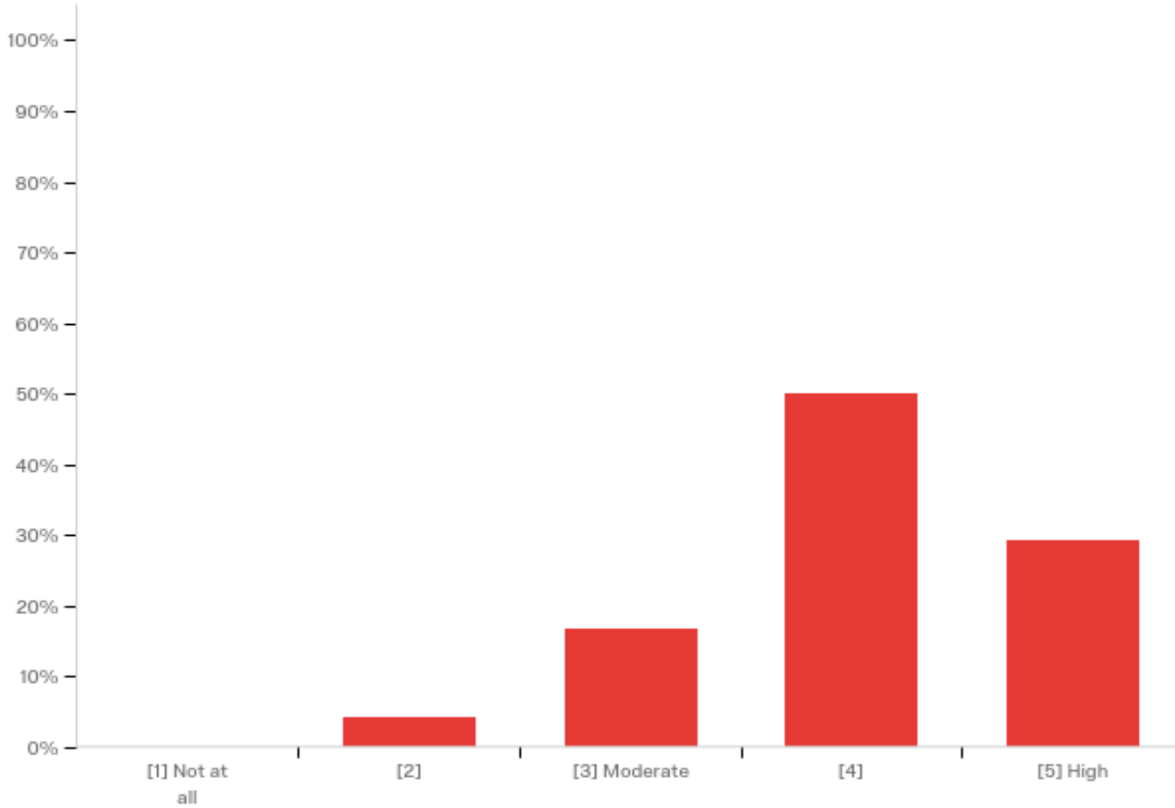
The following provides the current analysis across the full dataset for the survey of systems engineers. These overall results will be updated as additional data is collected. Organization-focused insights will also be crucial (See Section 4.1 for examples). Note: Questions 1-6 are the OCAI tool for the CVF and Questions 34 – 55 are the Qi Index, which are not repeated here.

7. What would you say the overall Status of systems engineers within your organization is:



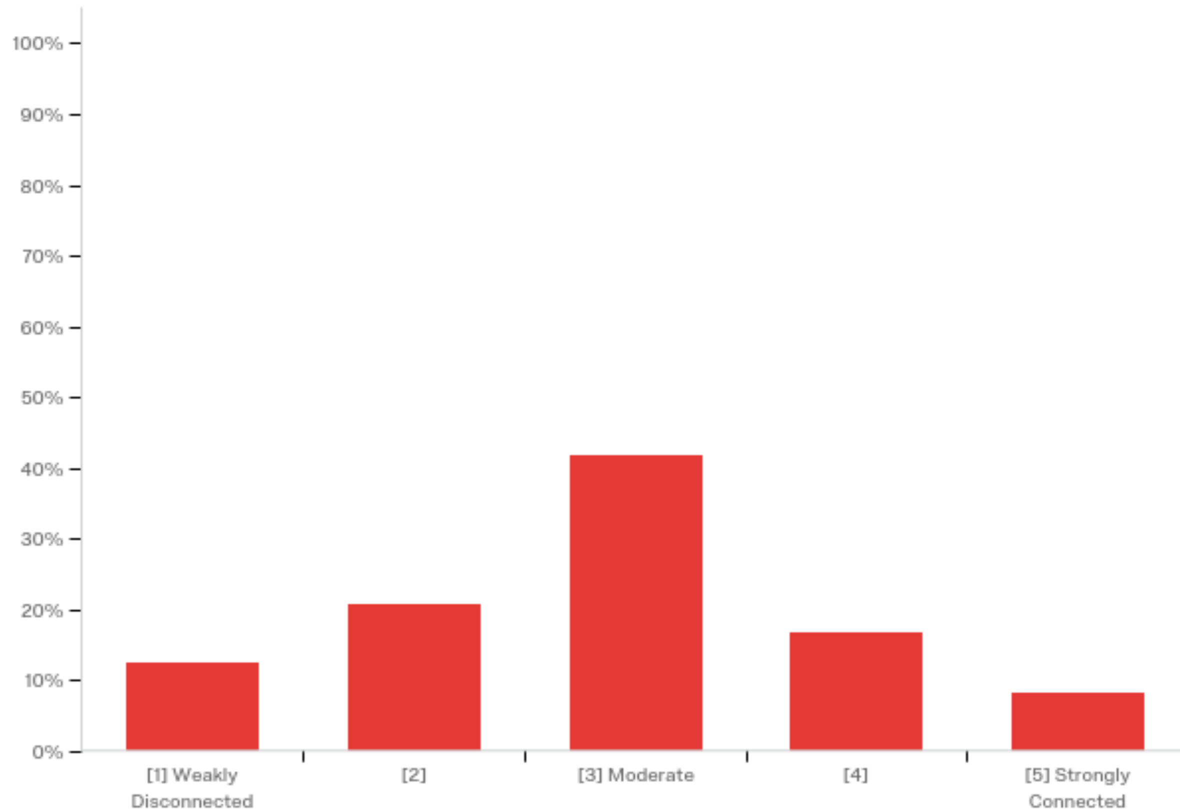
Q7 Please elaborate on your answer to the previous question, with examples if appropriate.

8. How Valued is systems engineering as a discipline in your organization?

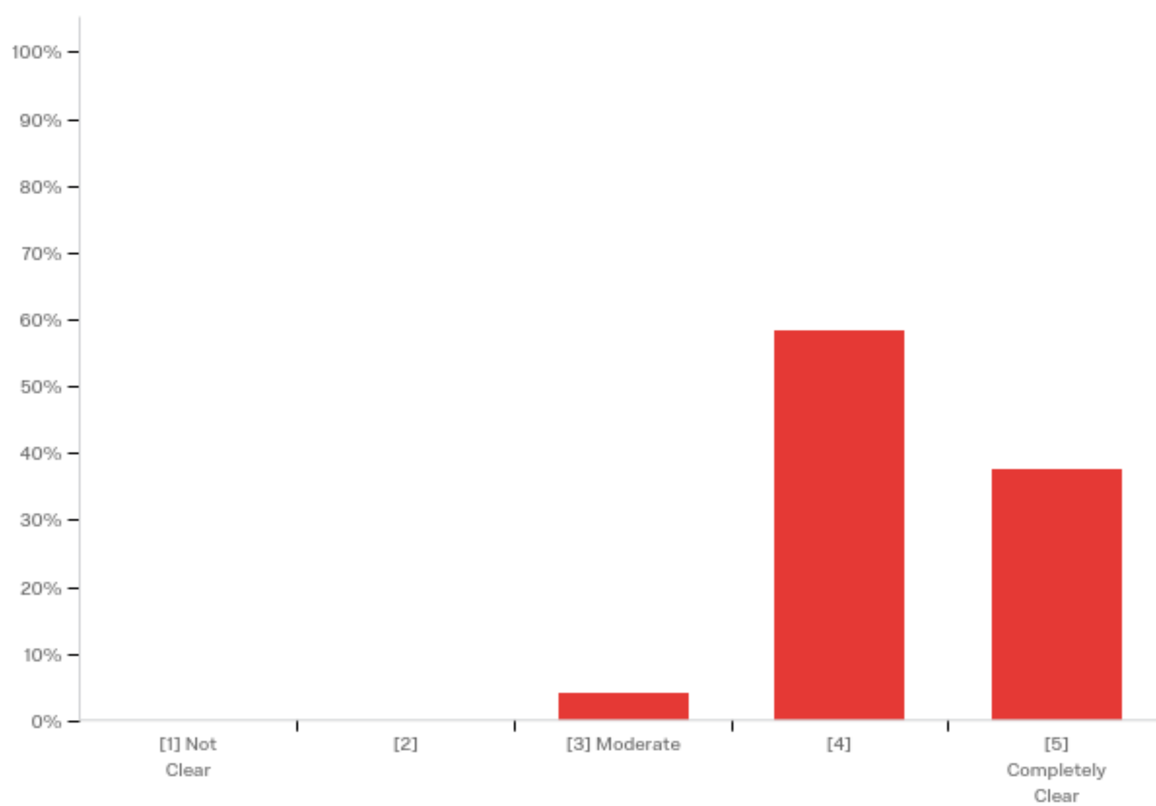


Q8 - Please elaborate on your answer to the previous question, with examples if appropriate.

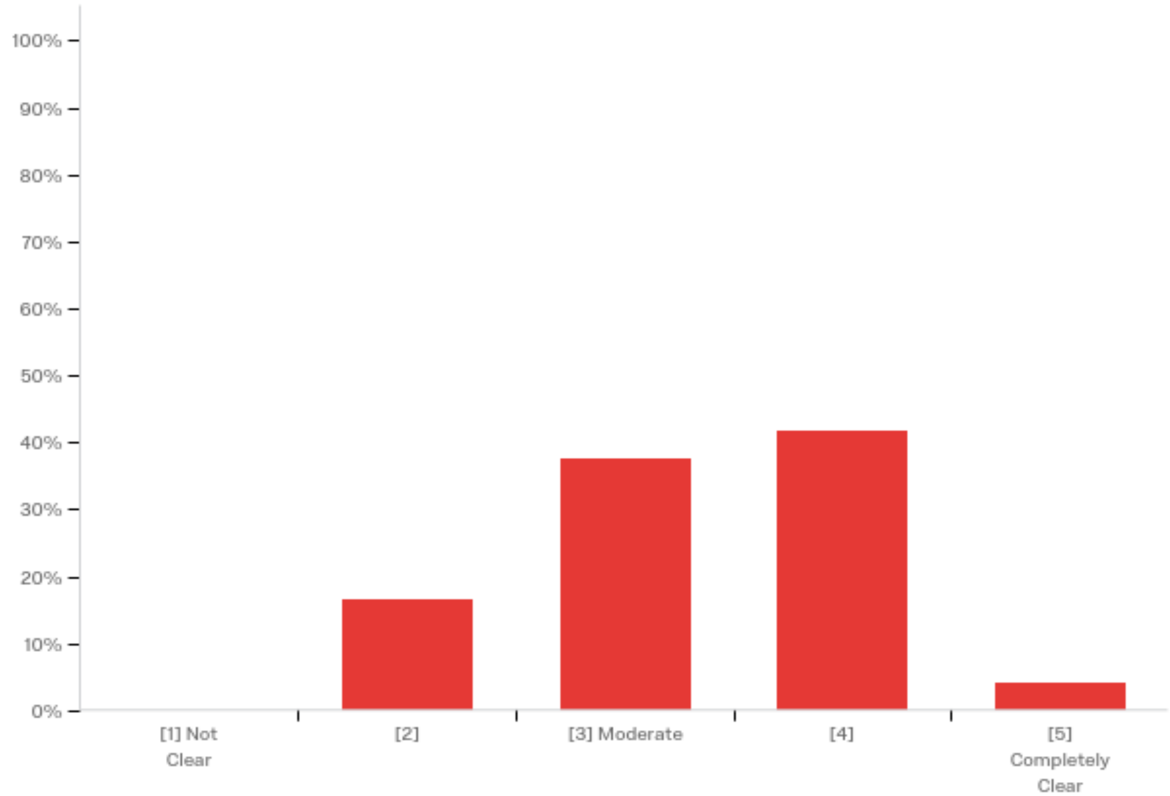
9. When you think of systems engineering as a profession, how Connected do you feel to the broader systems engineering community?



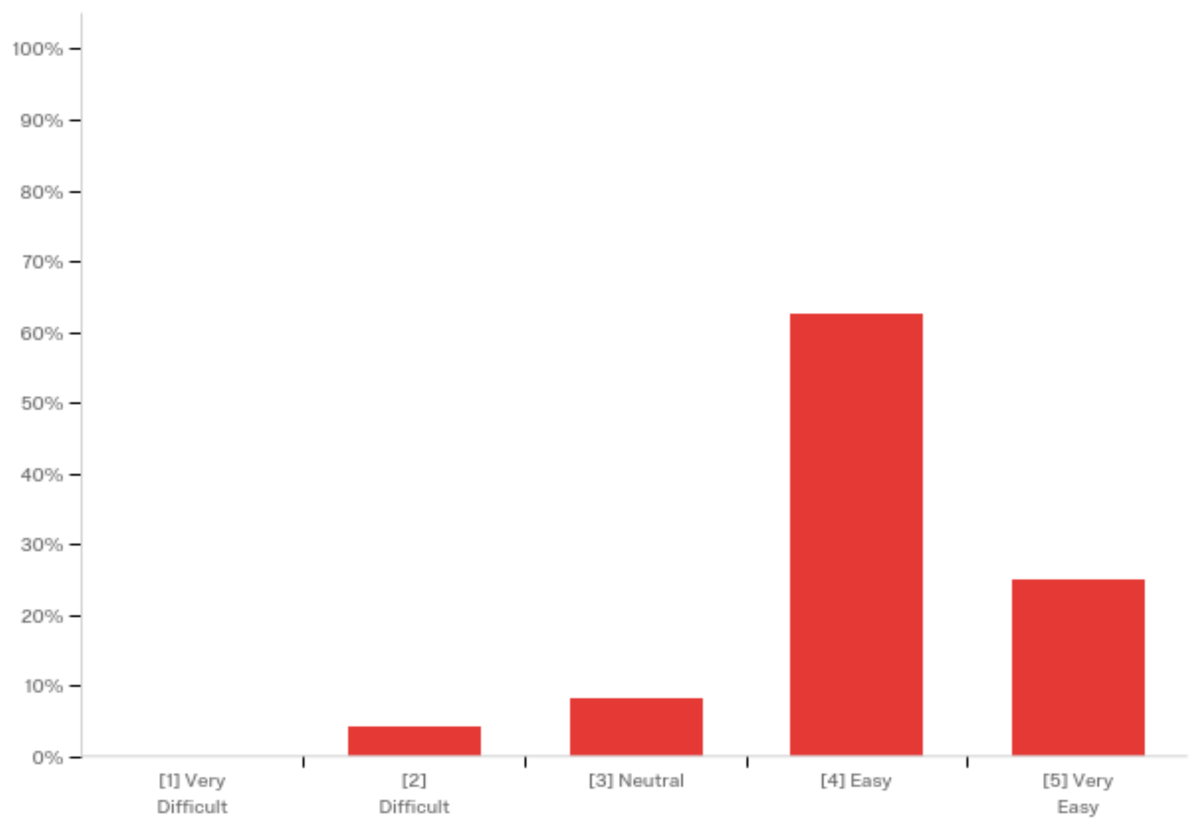
10. How Clear is your role as a systems engineer to you?



11. How do you think others on your team(s) would rate the Clarity of your role as a systems engineer right now?



14. Collaborating with peers in other functions on your project is:

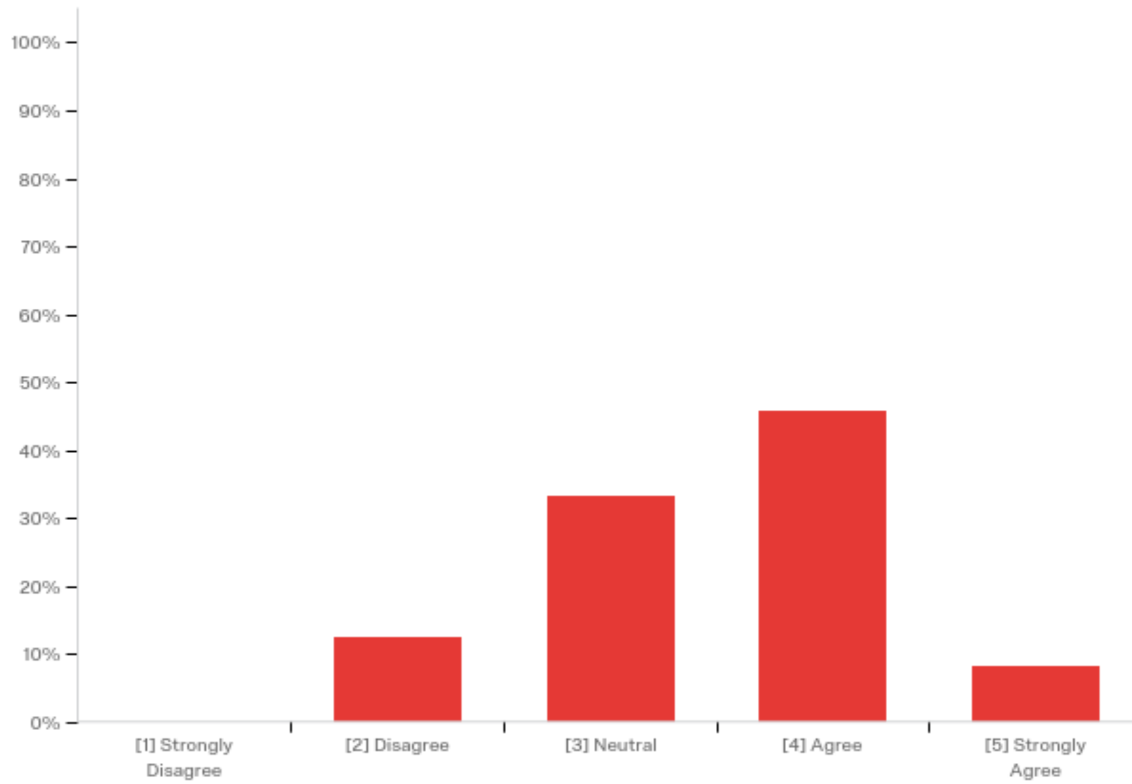


15. Thinking about the culture of the organization and about the SE culture within this organization, what aspects of “the way we do things around here” contribute to SE success?

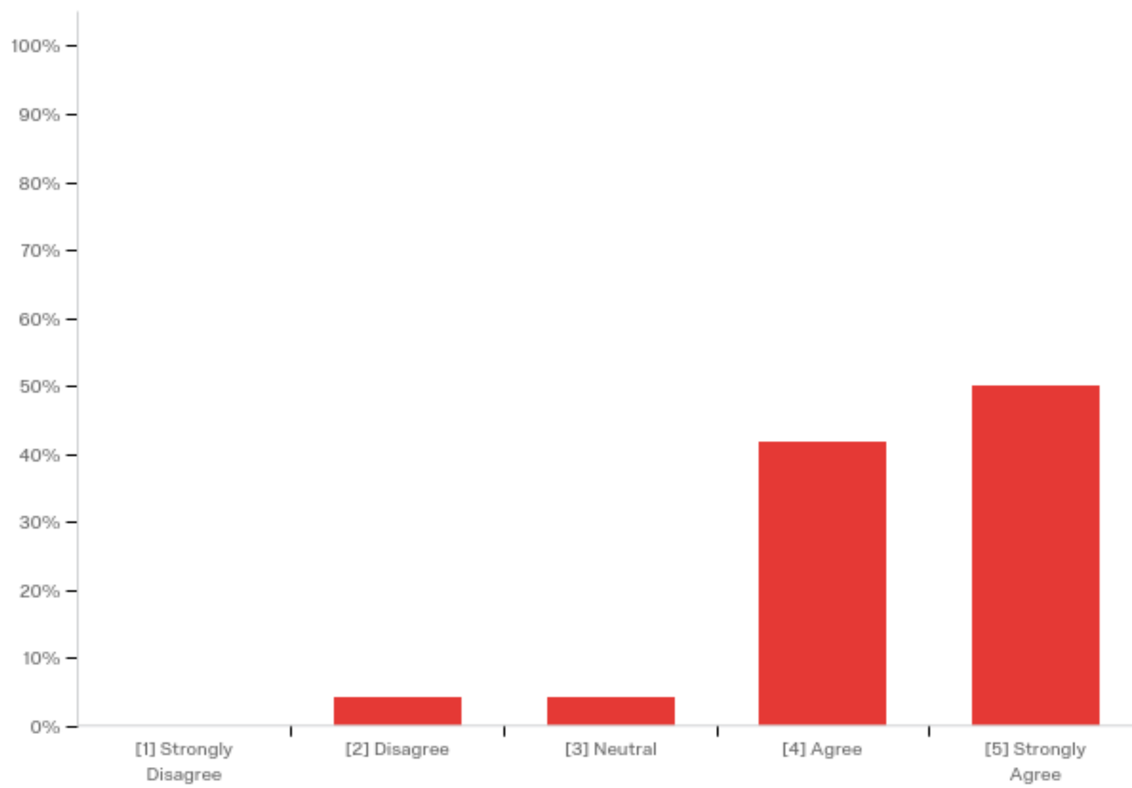
16. Thinking about the culture of the organization and about the SE culture within this organization, what aspects of “the way we do things around here” hinder SE success here?

Exploring Organizational Governance

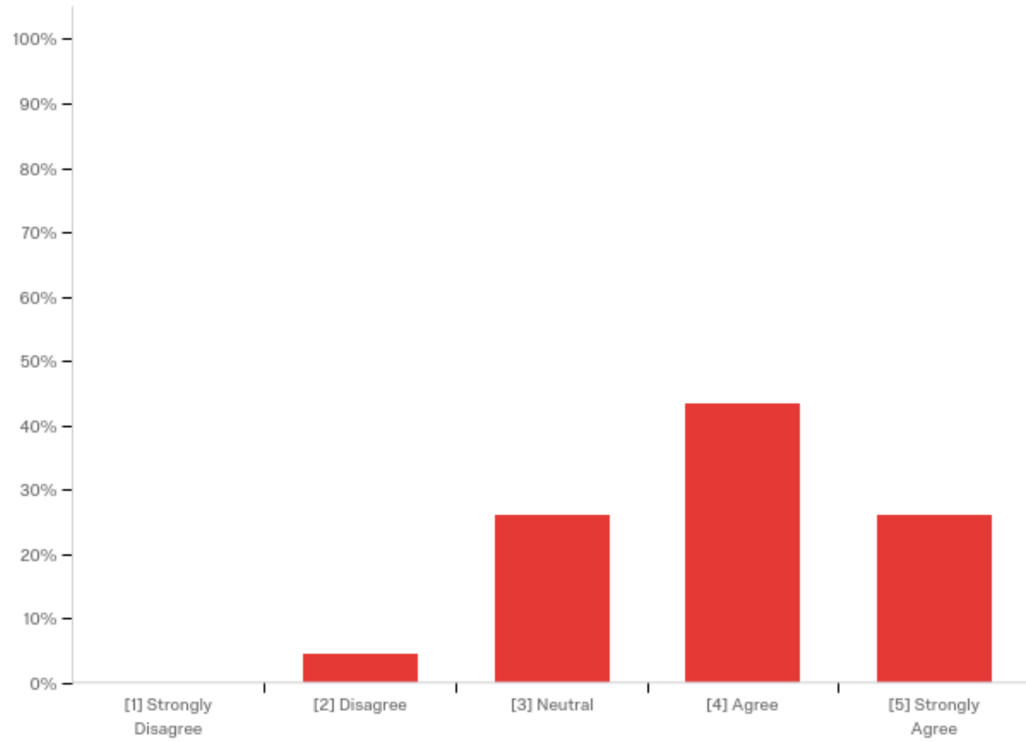
17. Diverse thinking is brought to bear on important decisions here.



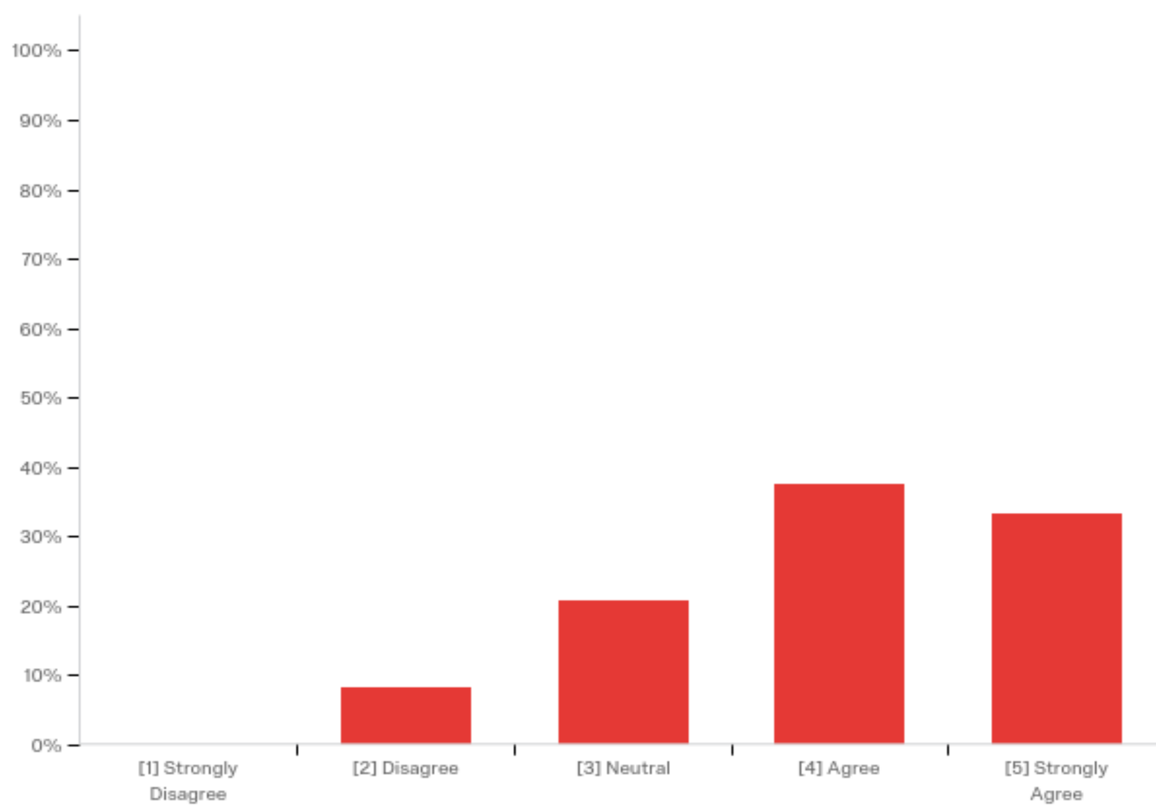
18. Systems engineering has an official role in making the most important technical decisions here.



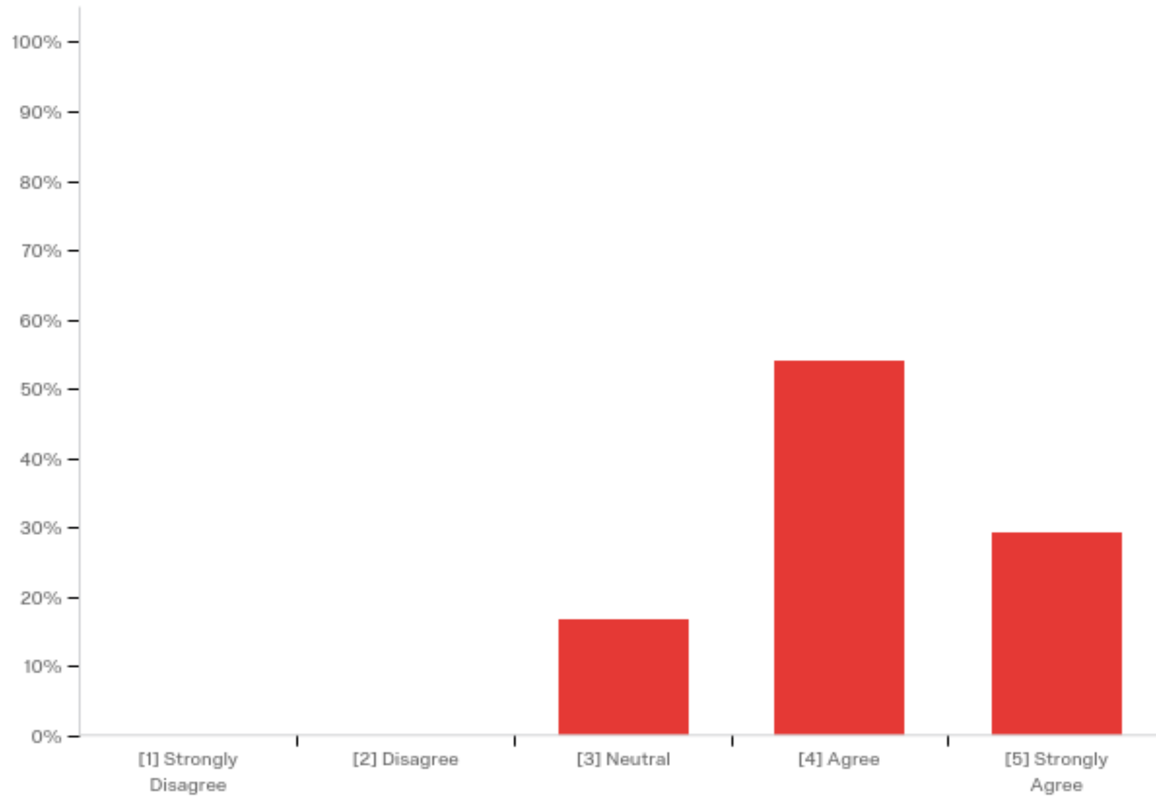
19. I have a direct impact on the most important technical decisions in my organization.



20. Senior executives visibly champion systems engineering as a critical discipline here.

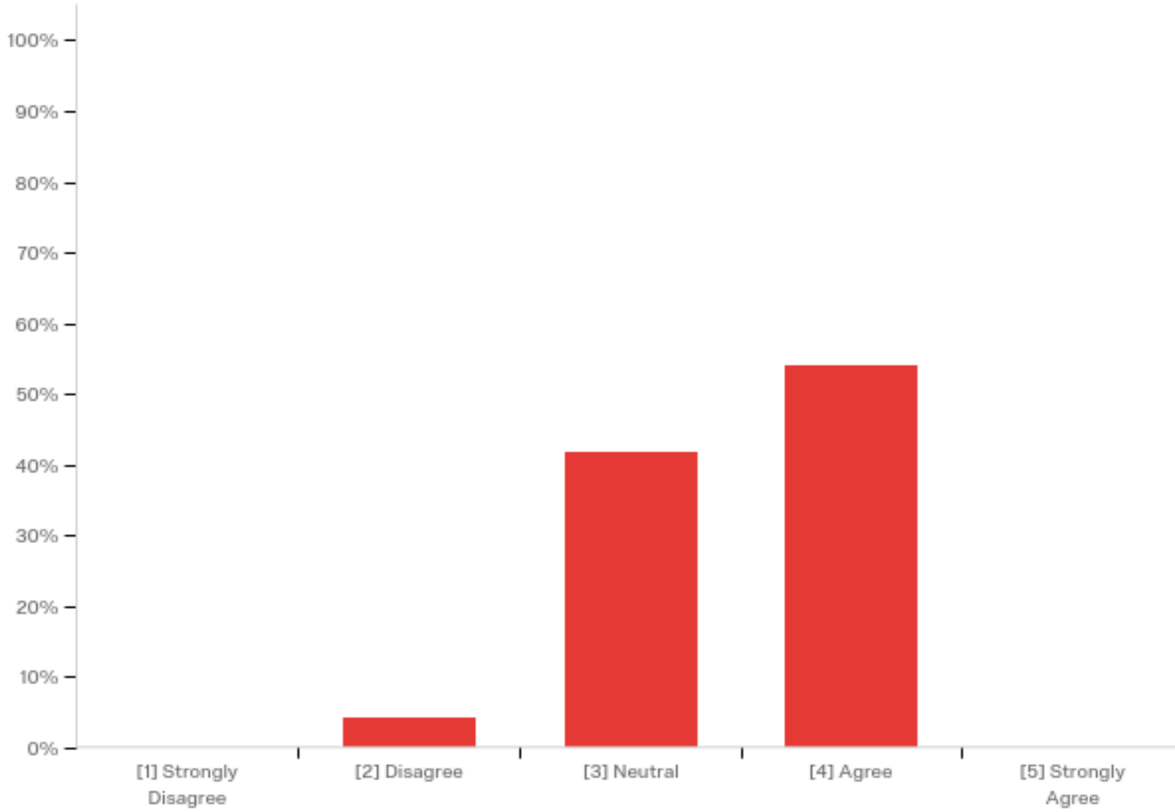


21. I see direct connections between my Systems Engineering activities and the mission of our overarching organization.

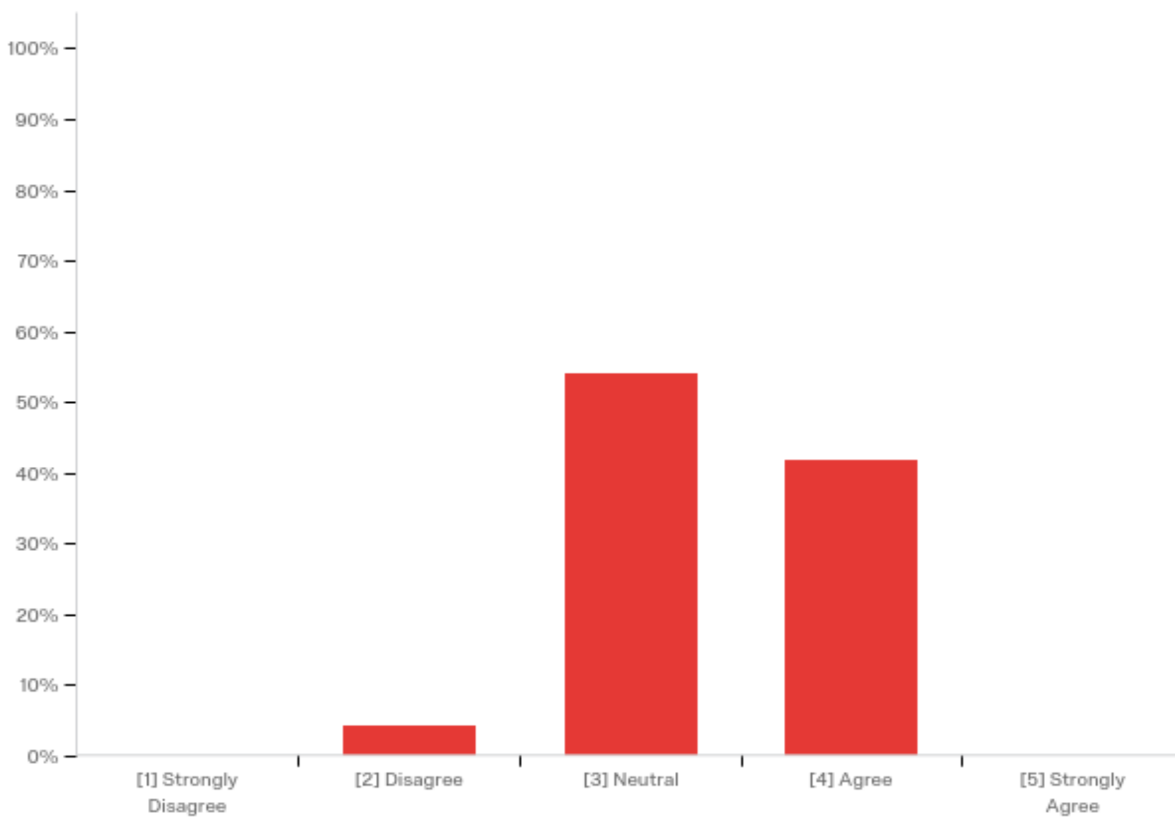


22. Describe the Systems Engineering approach(es) you use. (E.G. Vee model, spiral/incremental development, aligned with ISO 15288 or DoD 5000.02, agile, model-based, etc.)

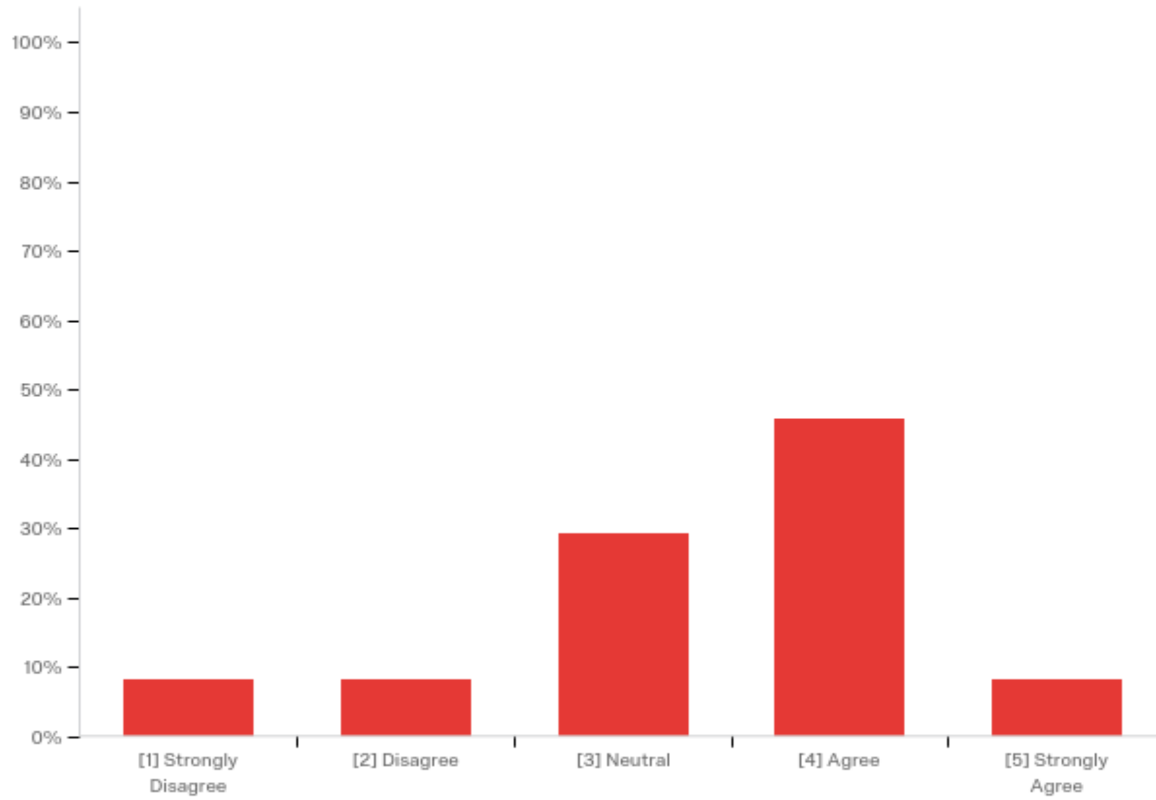
23. Overall, the way systems engineering is organized here is very effective.



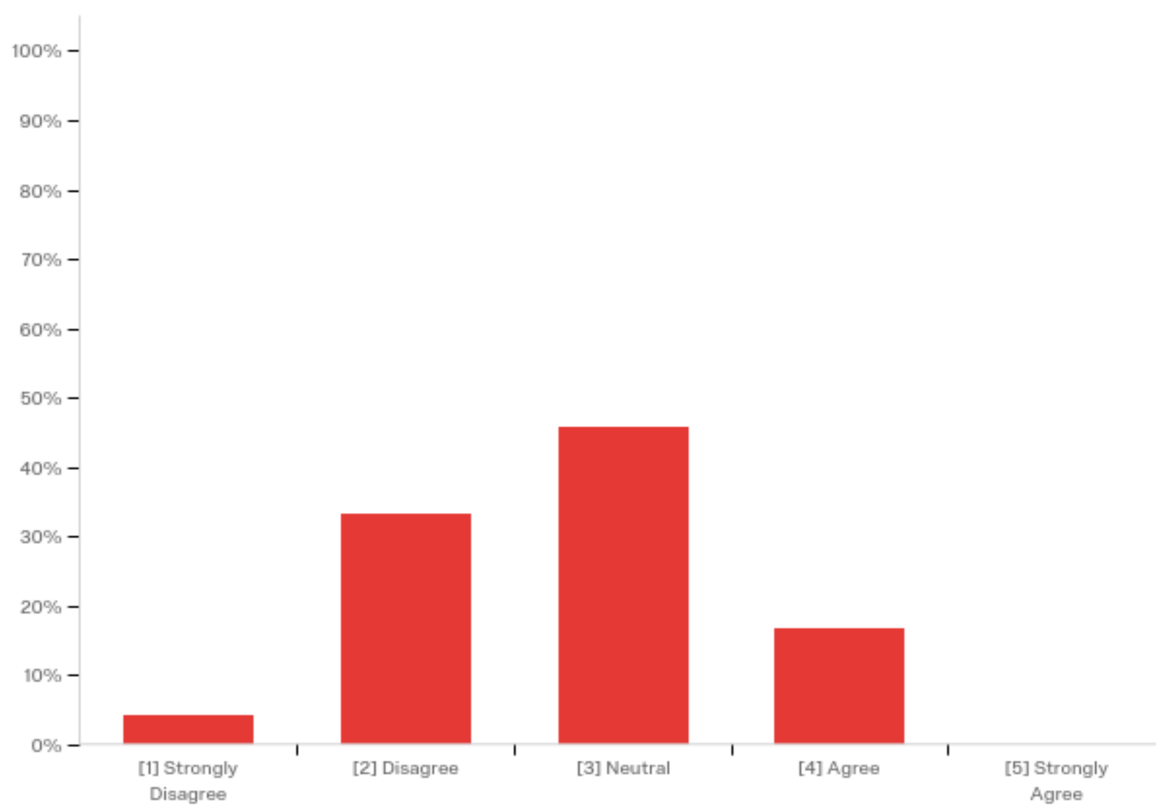
24. Overall, the systems engineering processes we use are very effective.



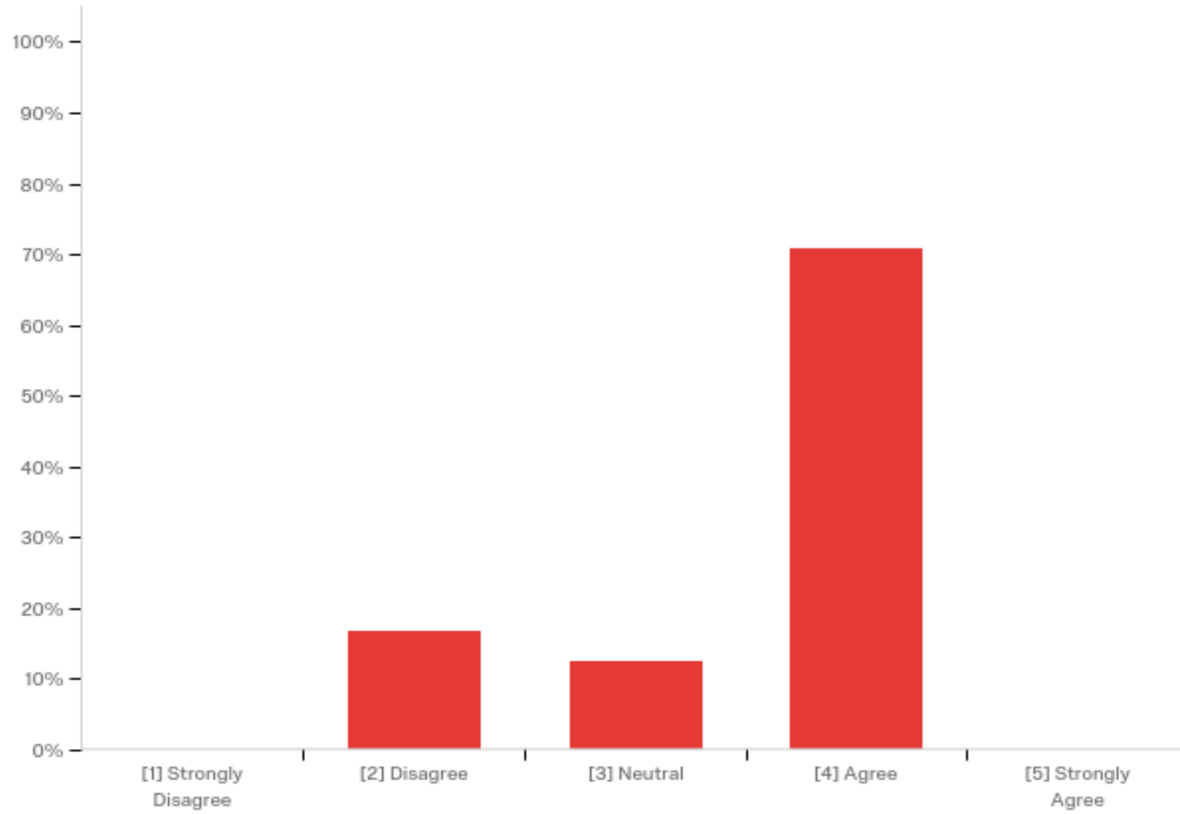
25. We have the tools we need to do systems engineering effectively.



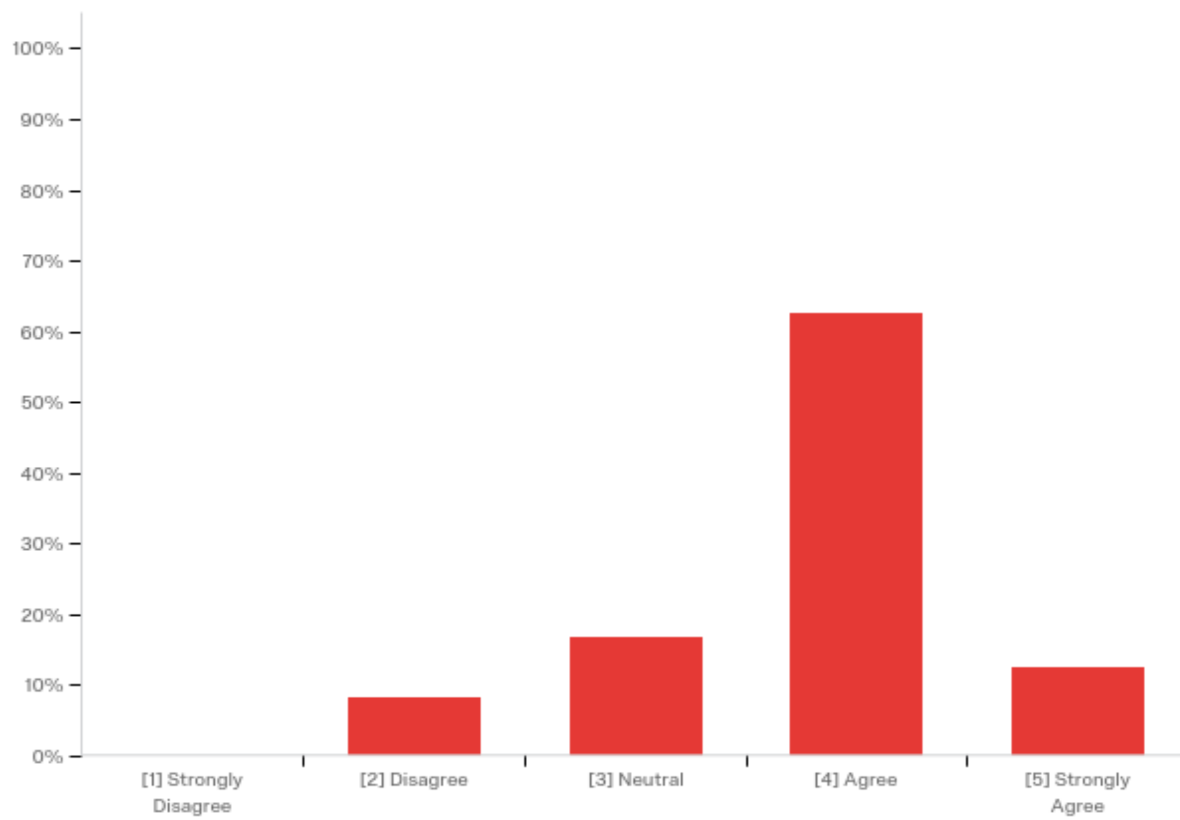
26. We use leading-edge systems engineering processes and tools here.



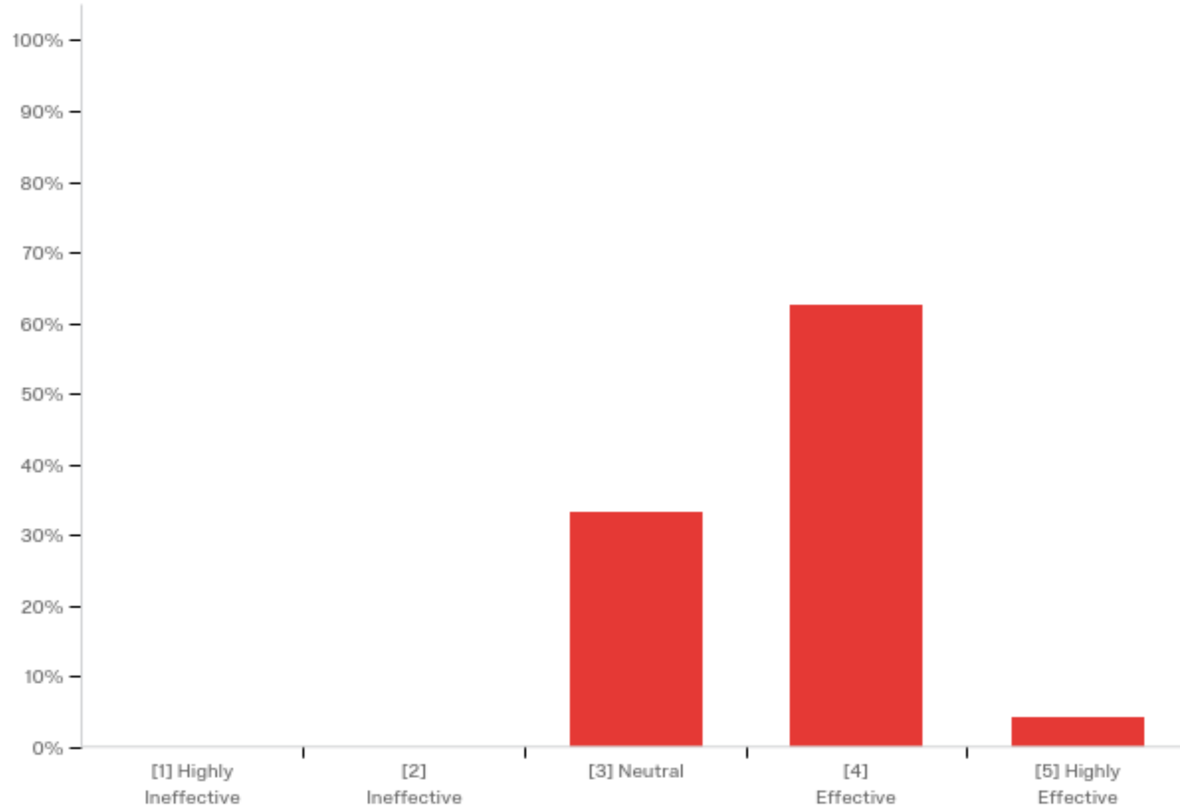
29. We have the right number of systems engineers on my project or program.



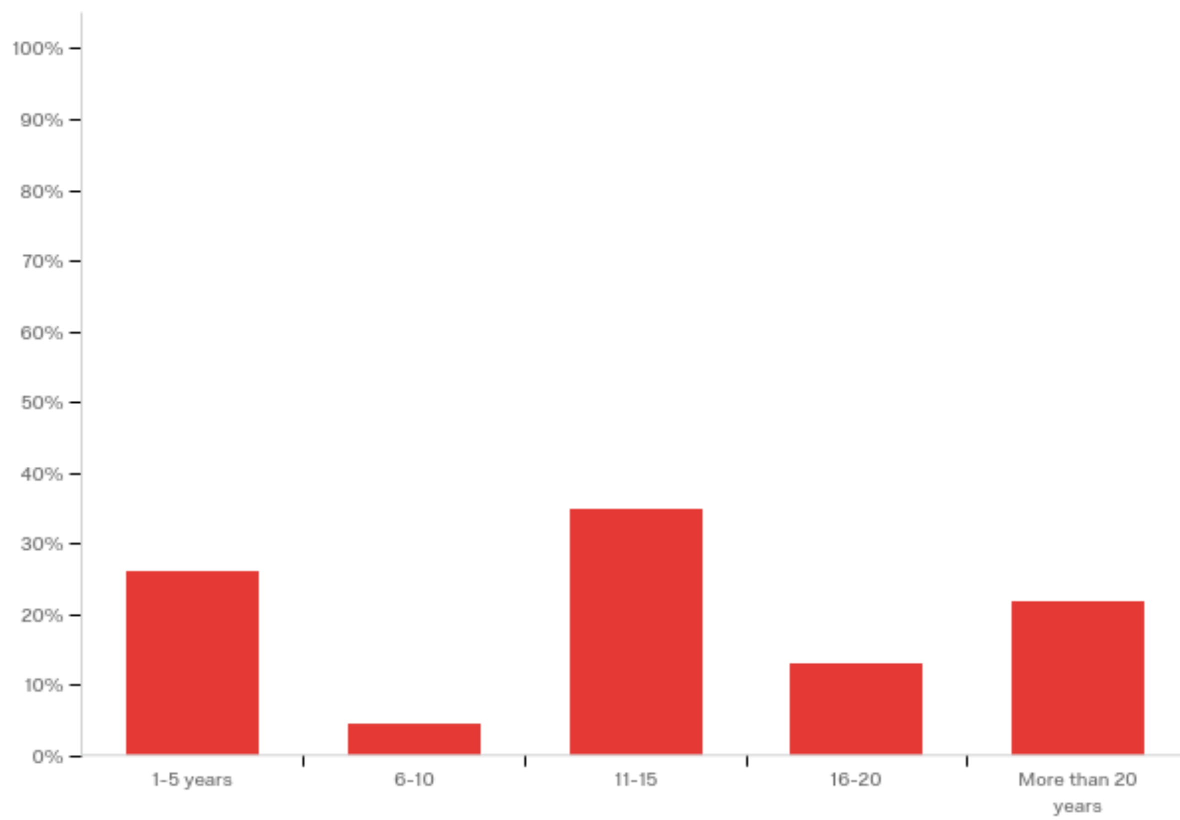
30. Our systems engineers have the skills required to succeed.



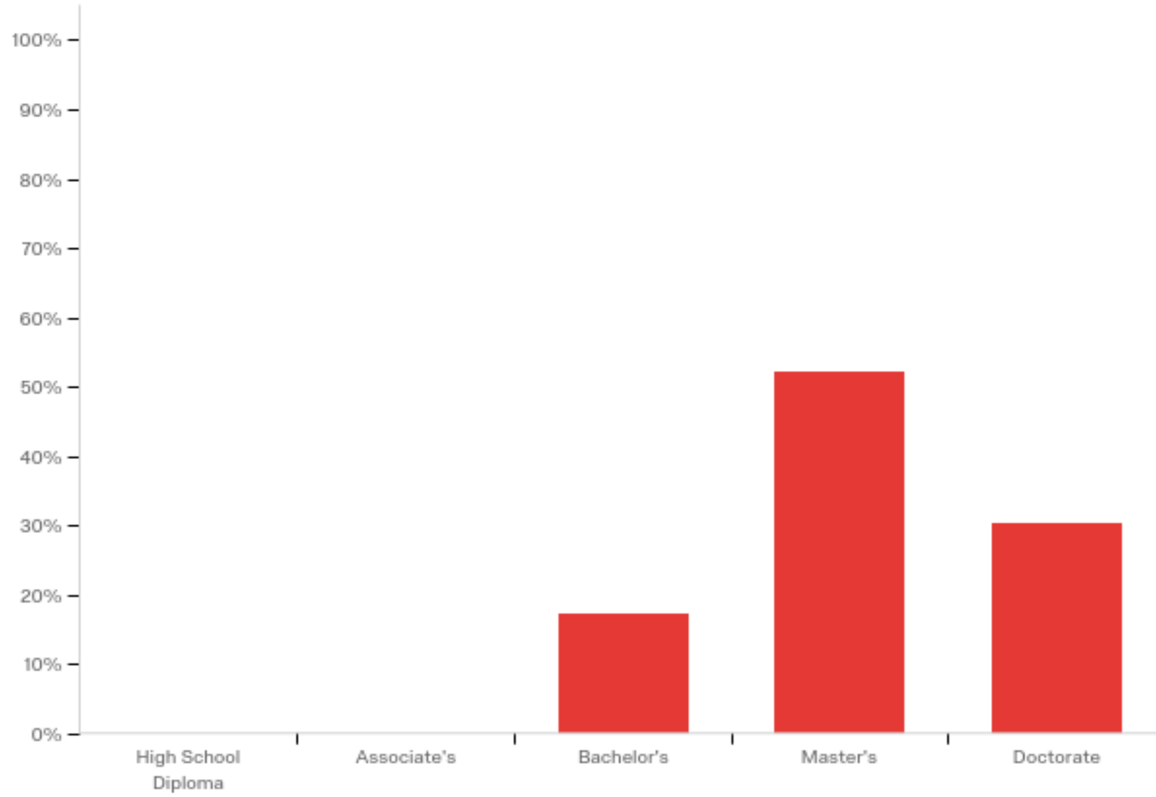
31. Overall, how effective is systems engineering here?



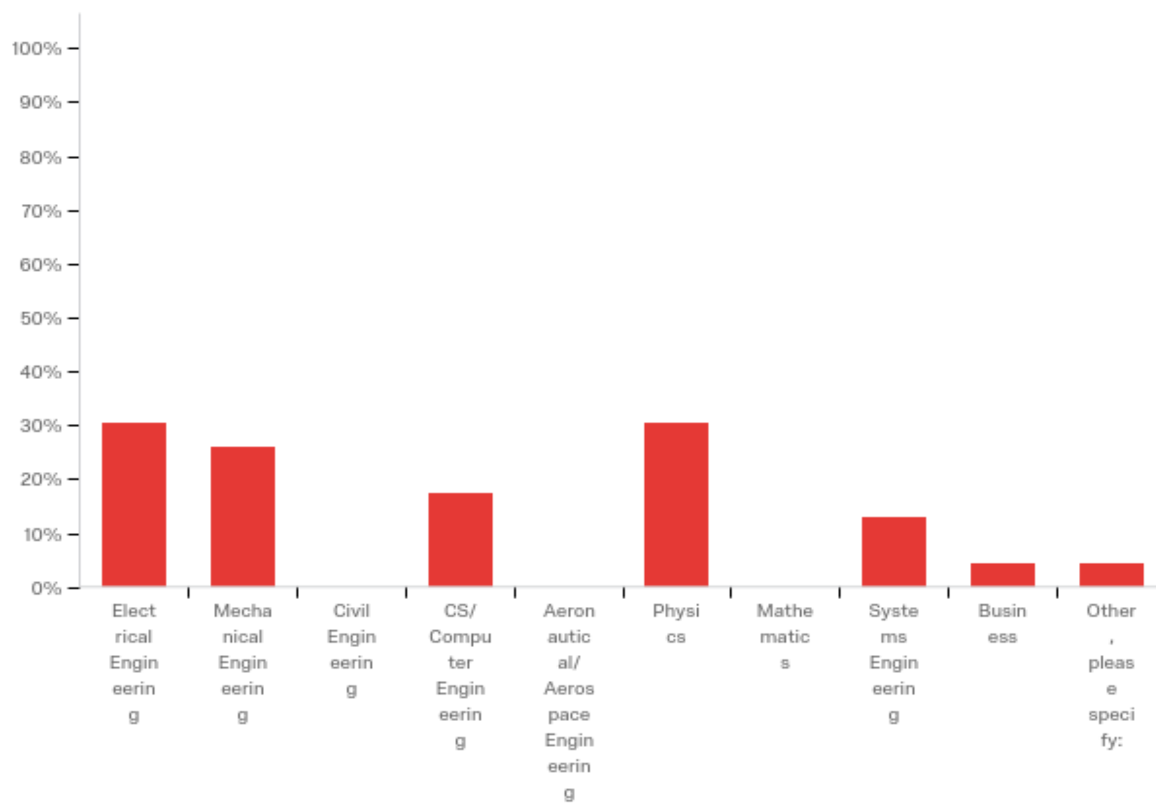
56. Experience in systems engineering:



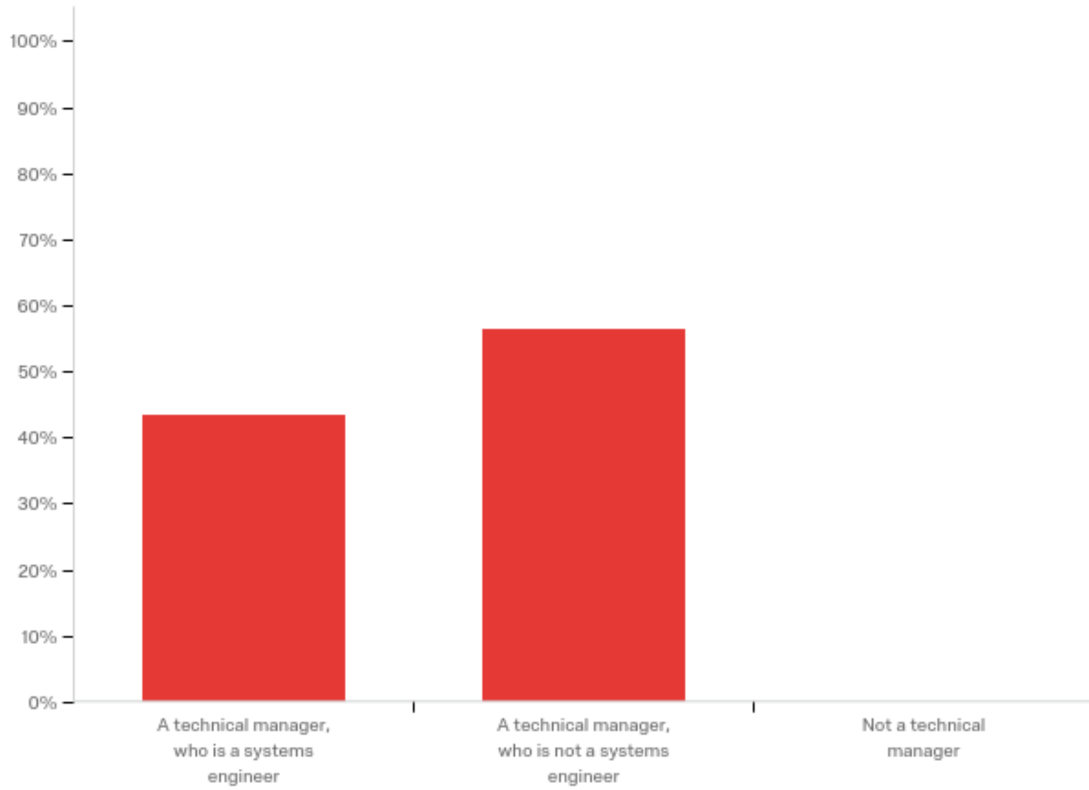
58. What is the highest level of school you have completed or the highest degree you have received?



59. Fields of study:

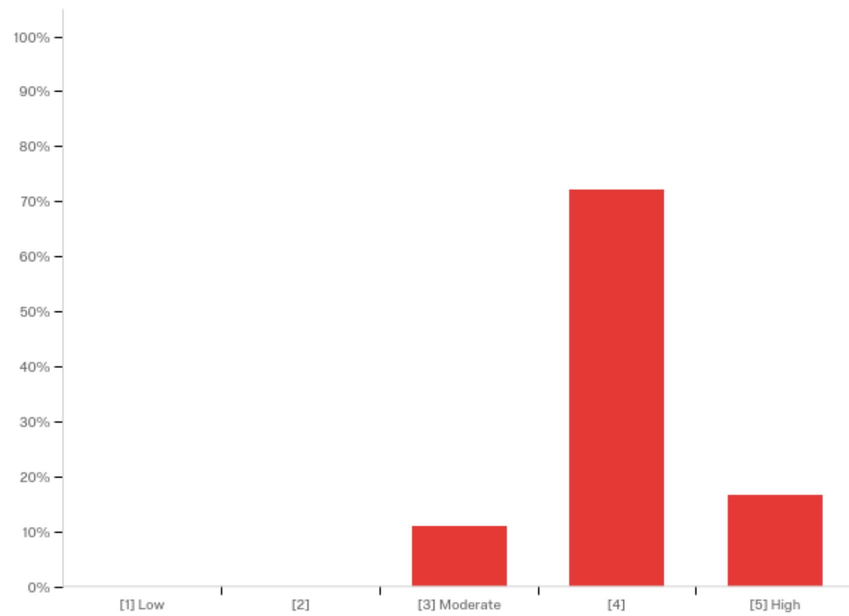


60. The person I report to is:



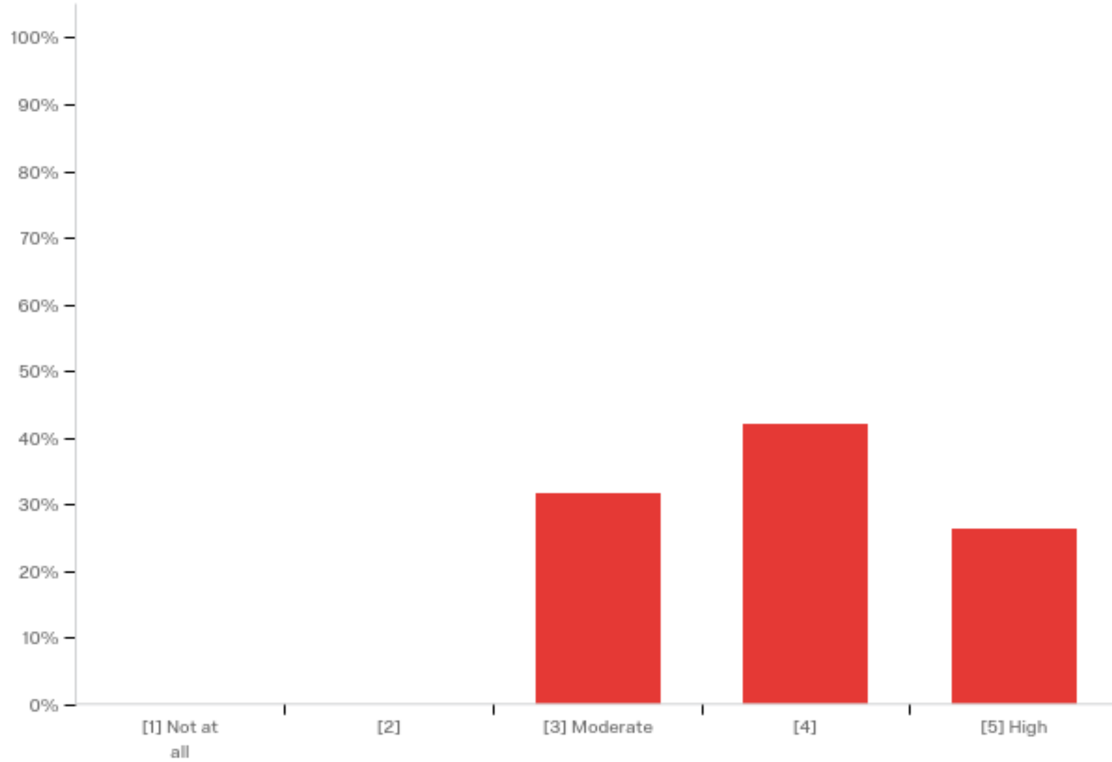
The following provides the current analysis across the full dataset for the managers, peers, and leadership survey. These overall results will be updated as additional data is collected. Organization-focused insights will also be crucial (See Section 4.1 for examples). Note: Questions 1-6 are the OCAI tool for the CVF and Questions 32 – 54 are the Qi Index, which are not repeated here.

7. What would you say the overall Status of systems engineers within your organization is:

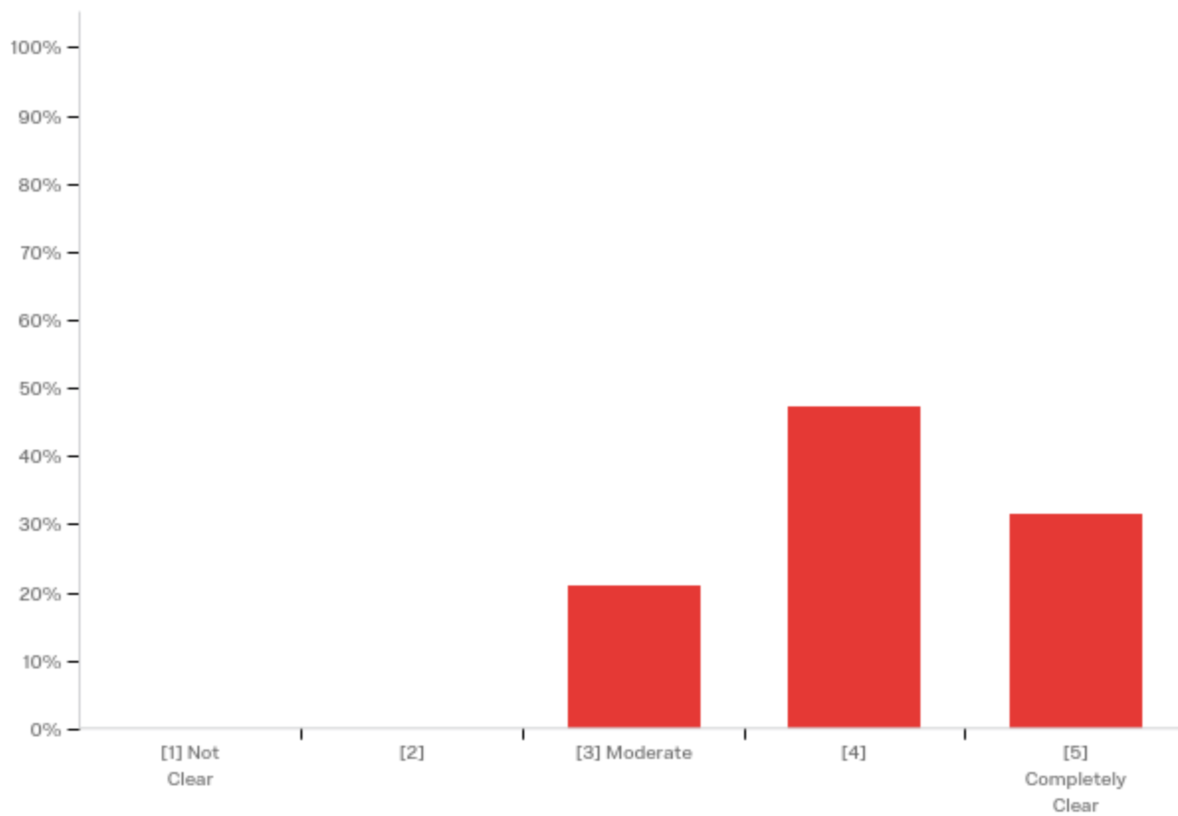


Q7 Please elaborate on your answer to the previous question, with examples if appropriate.

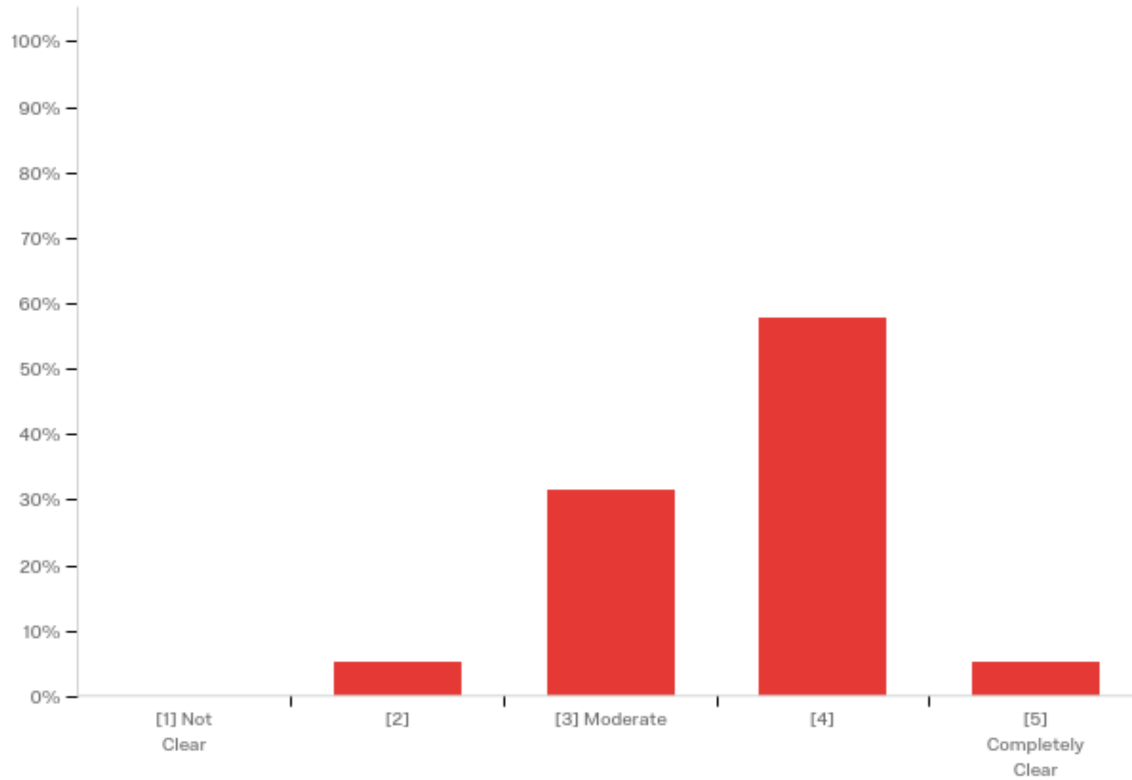
8. How Valued is systems engineering as a discipline in your organization?



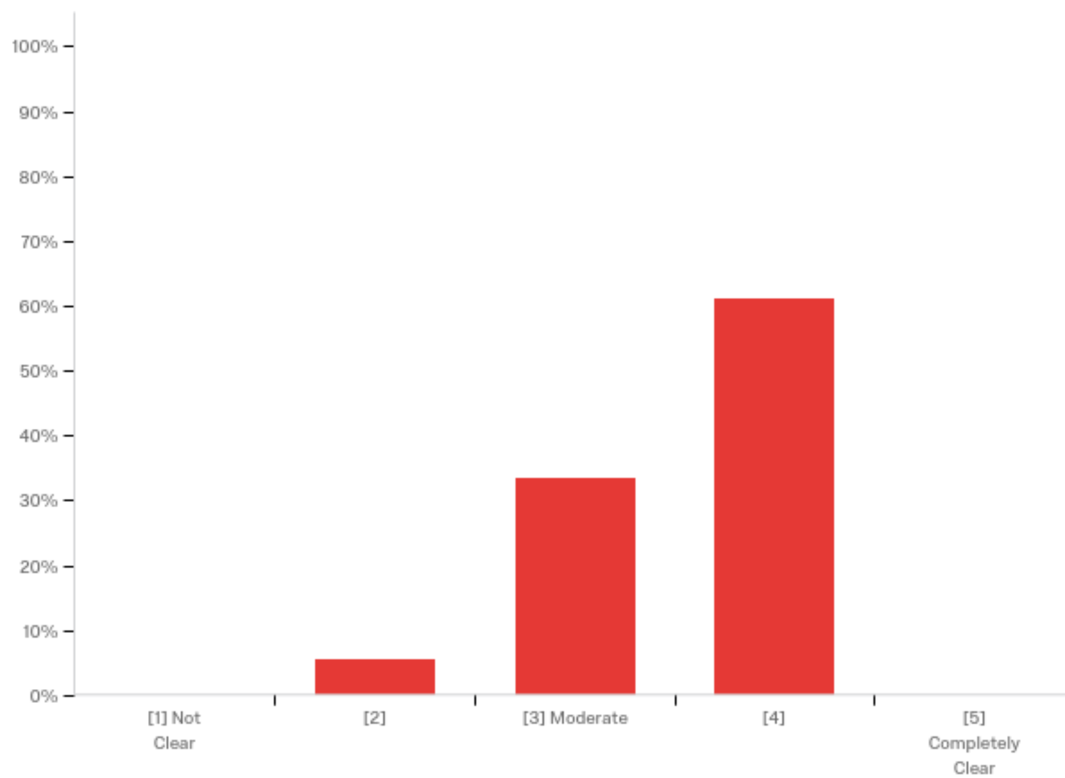
9. How Clear is the role of systems engineers in your organization to you?



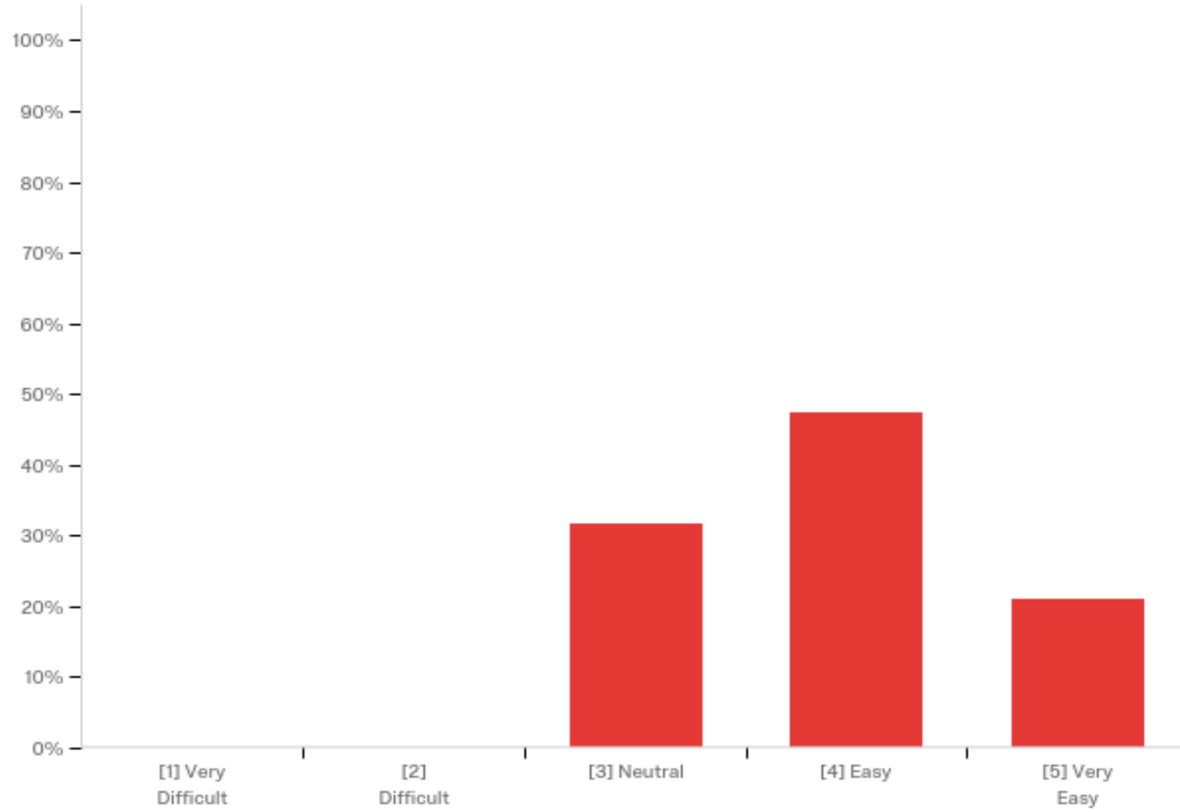
10. How do you think systems engineers in your organization would rate the clarity of their role right now?



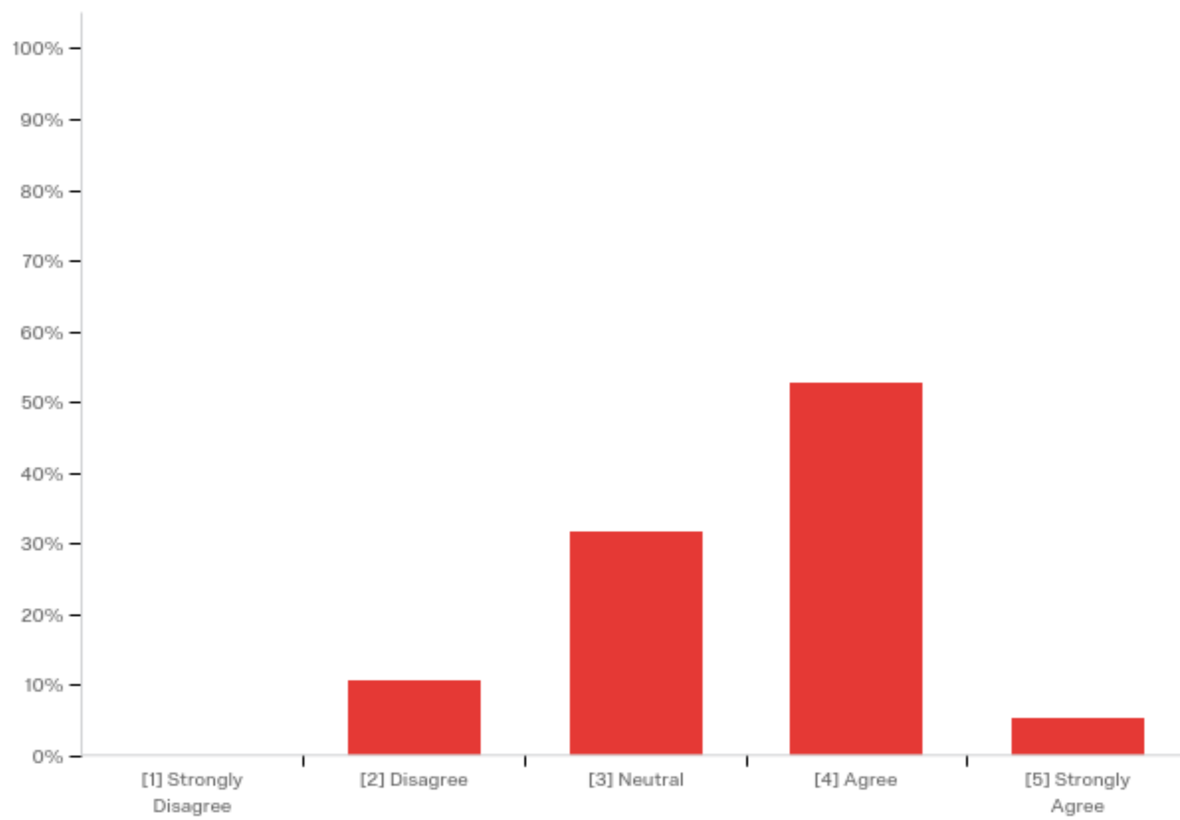
11. How do you think others on your team(s) would rate the Clarity of your role as a systems engineer right now?



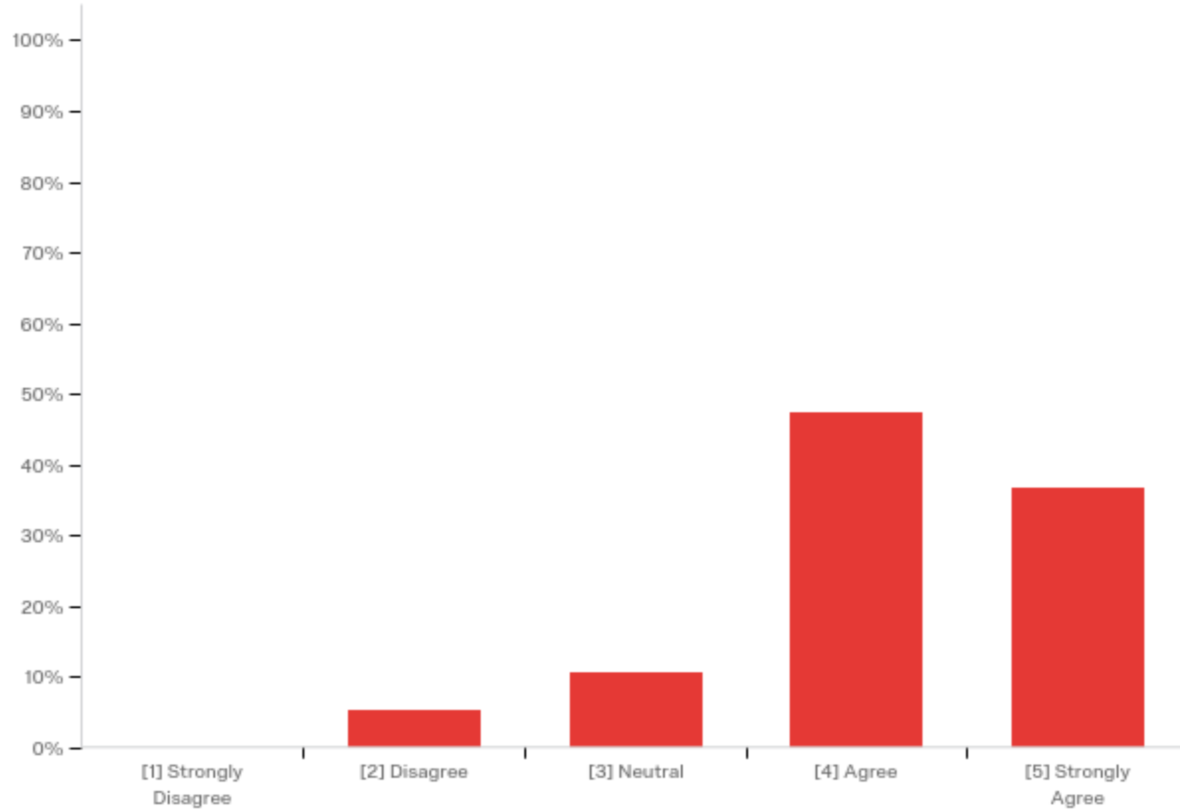
13. Collaborating with systems engineers on my project is:



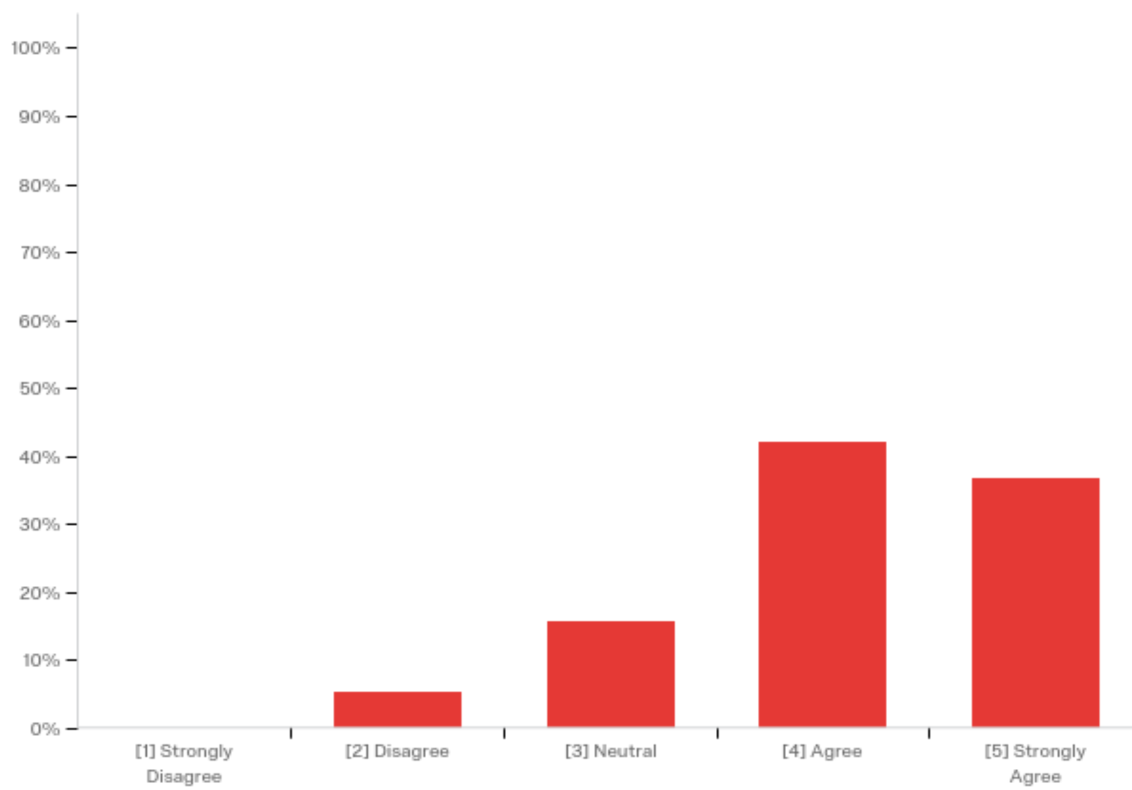
16. Diverse thinking is brought to bear on important decisions here.



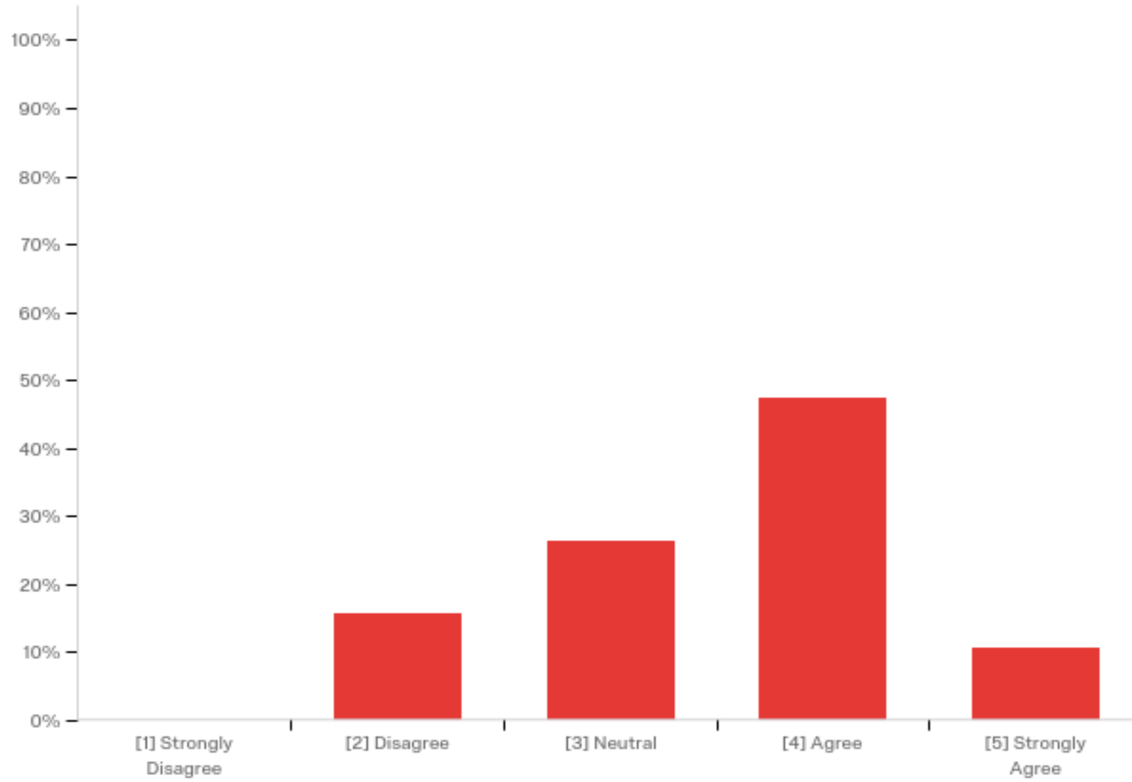
17. Systems engineering has an official role in making the most important technical decisions here.



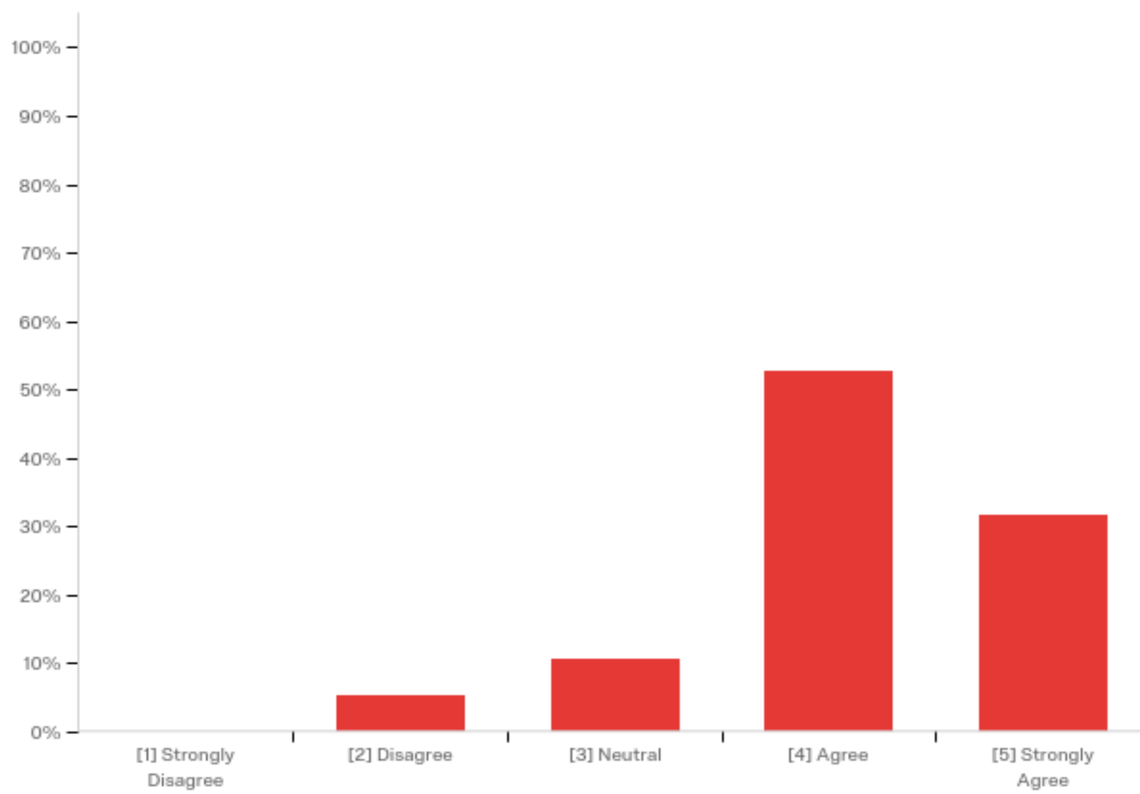
18. Systems engineers have a direct impact on the most important technical decisions in my organization.



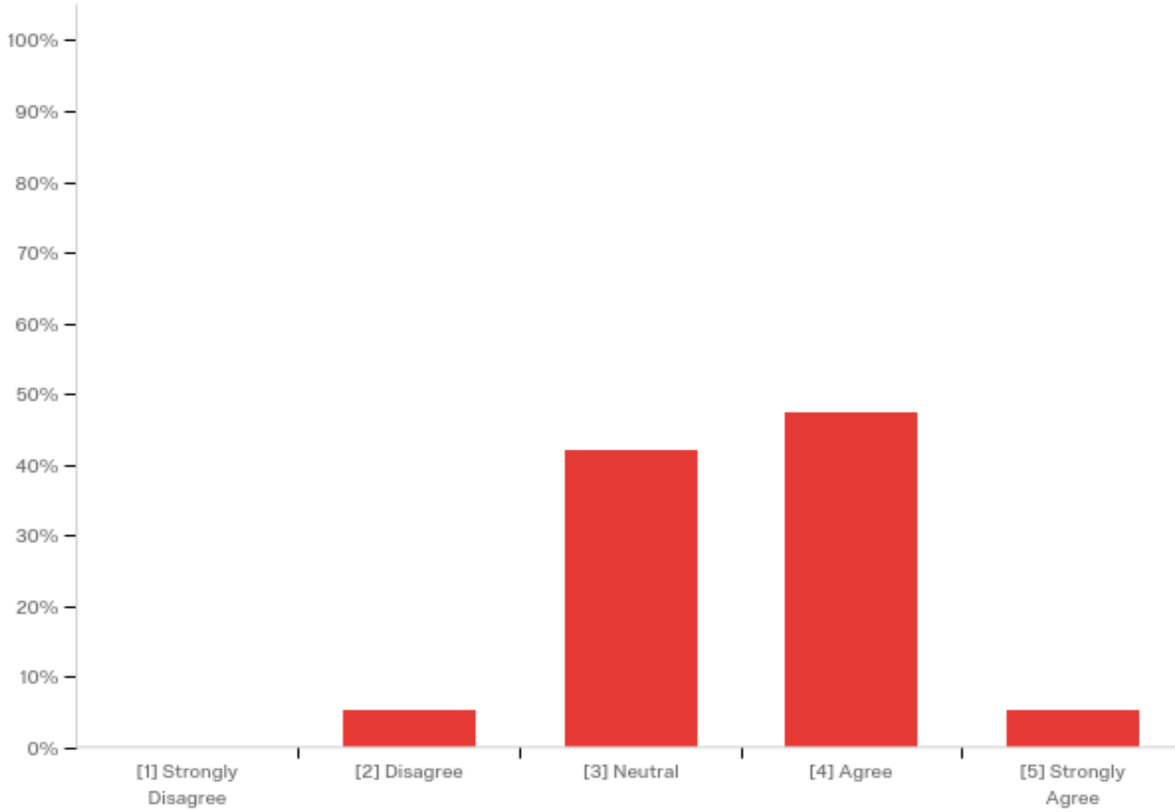
19. Senior executives visibly champion systems engineering as a critical discipline here.



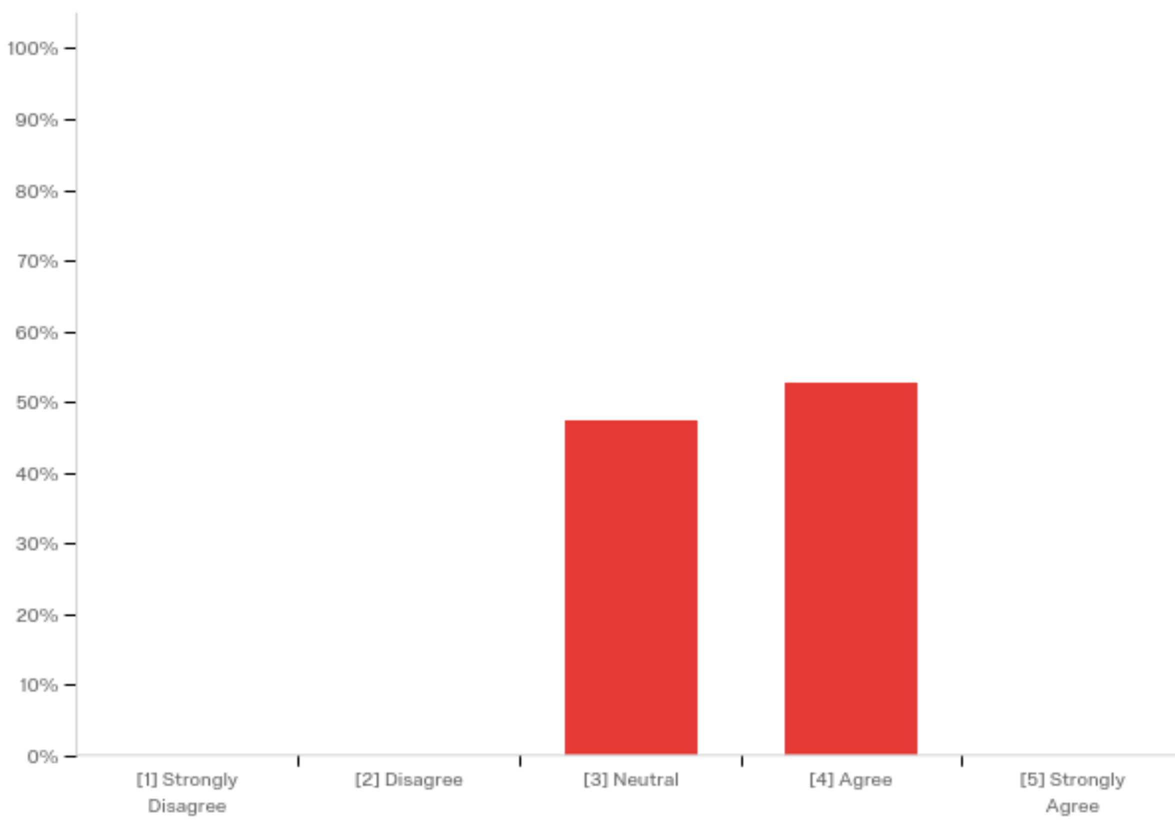
20. I see direct connections between systems engineering activities and the mission of our overarching organization.



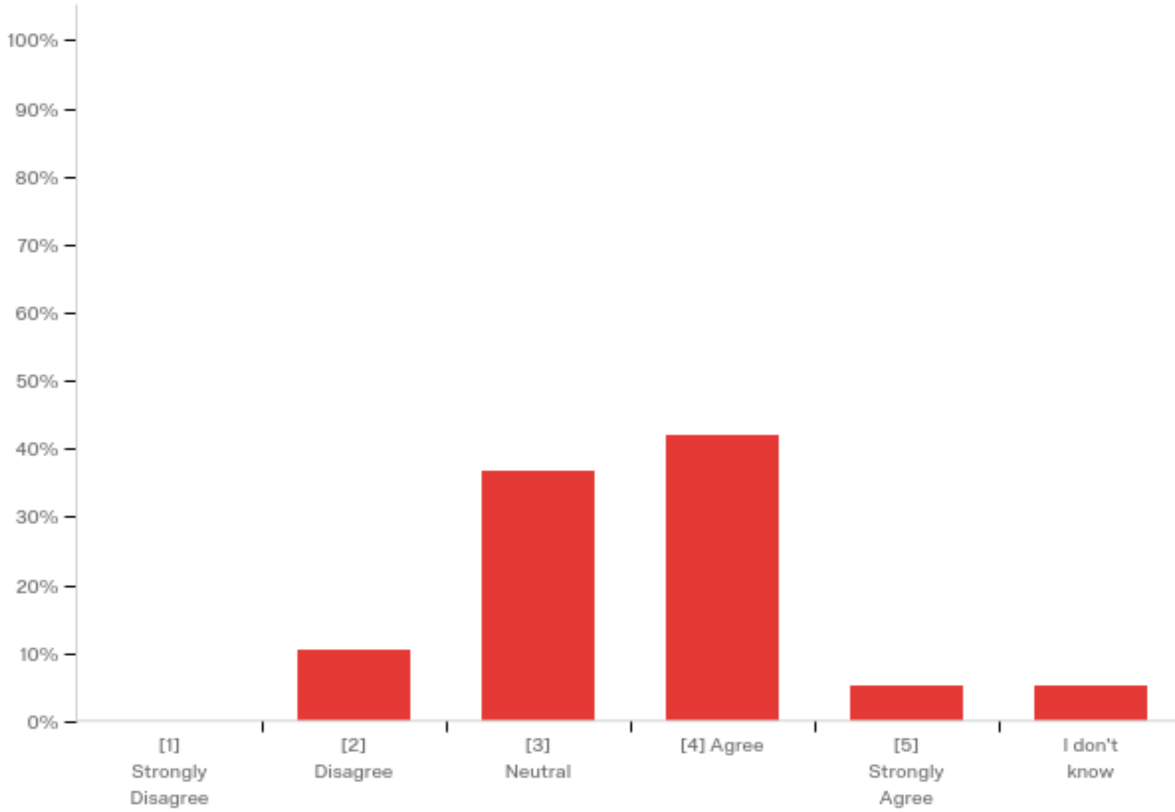
22. Overall, the way systems engineering is organized here is very effective.



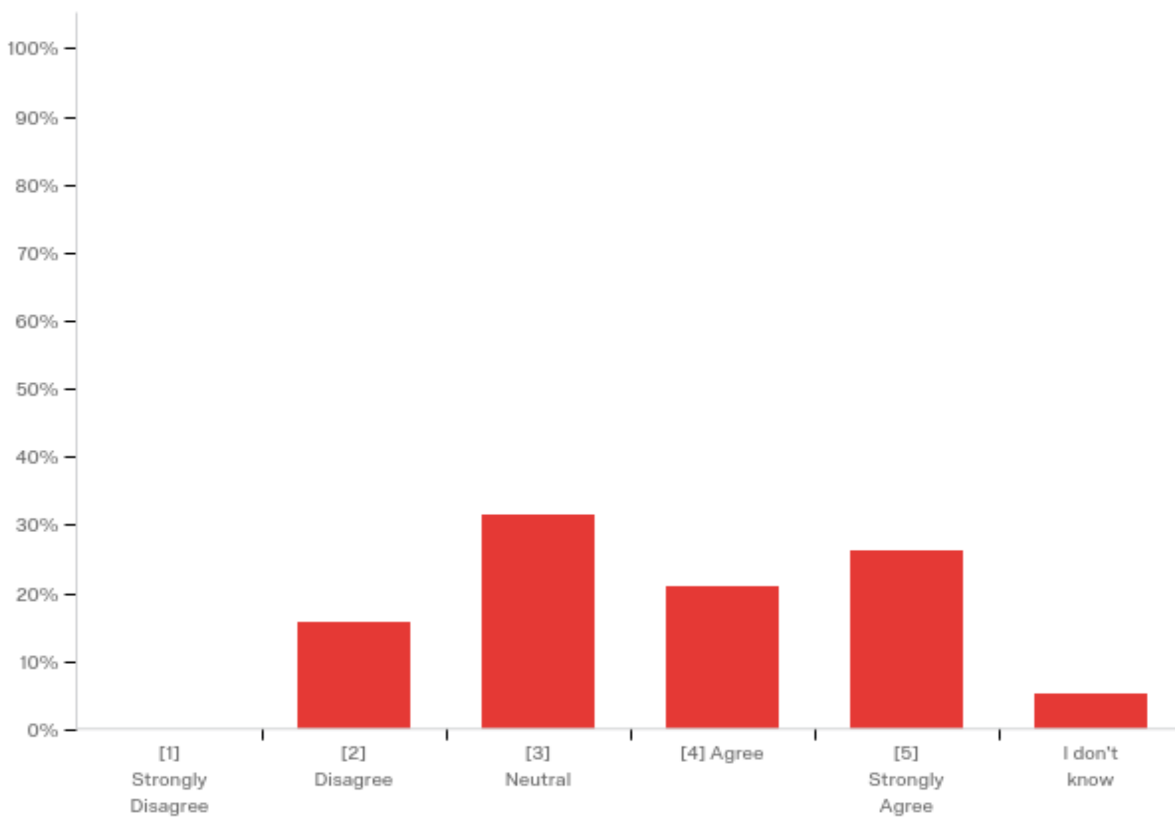
23. Overall, the systems engineering approaches we use are very effective.



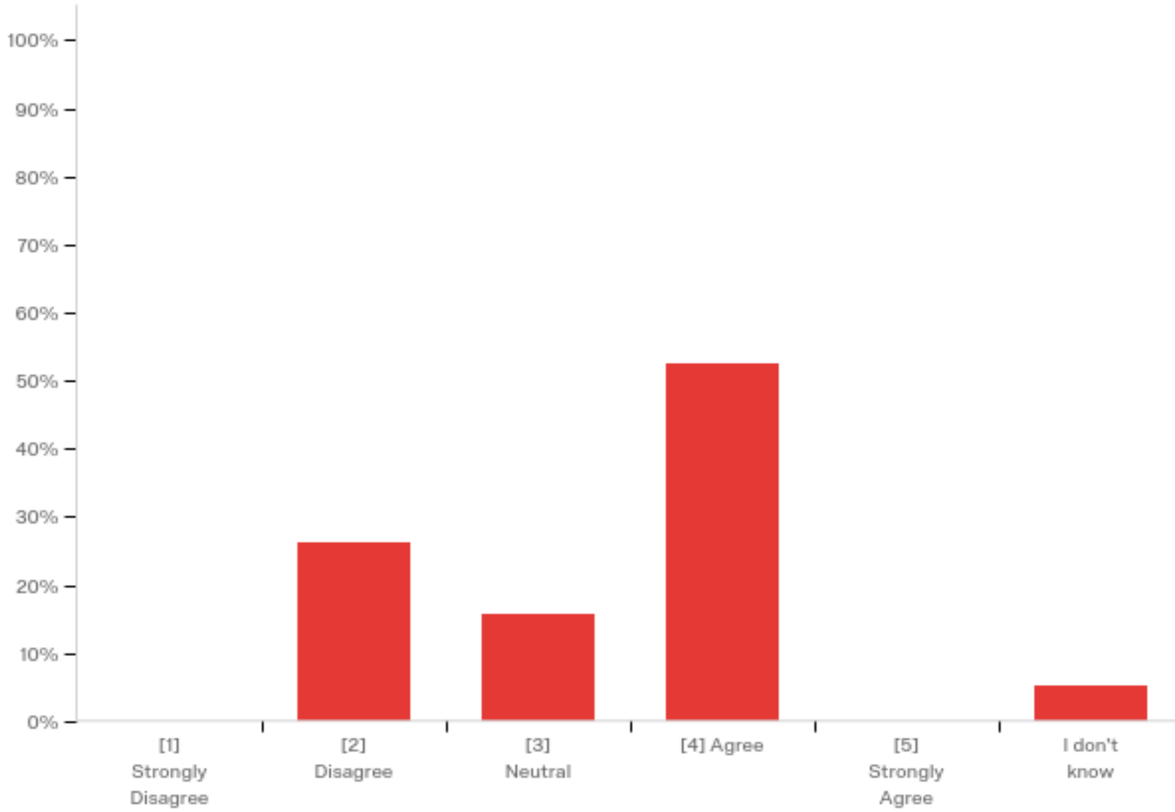
24. Systems engineers have the tools they need to do systems engineering effectively.



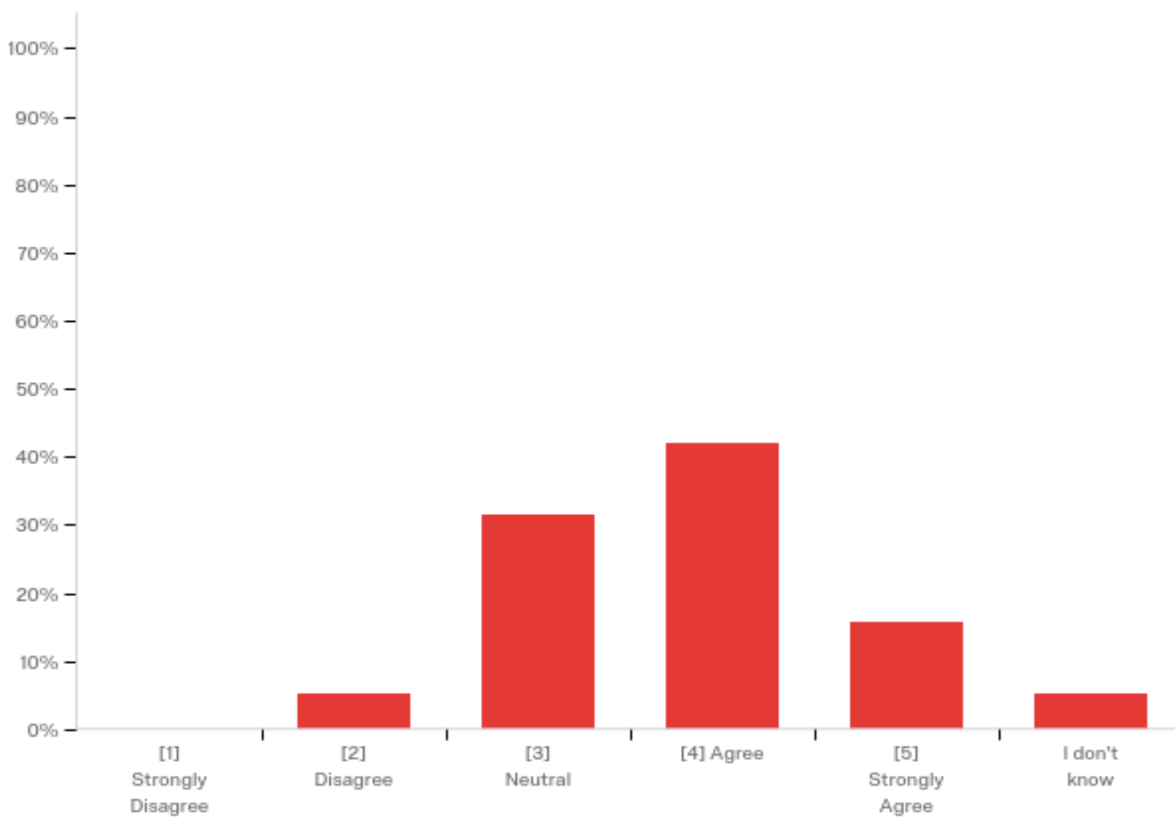
25. We use leading-edge systems engineering processes and tools here.



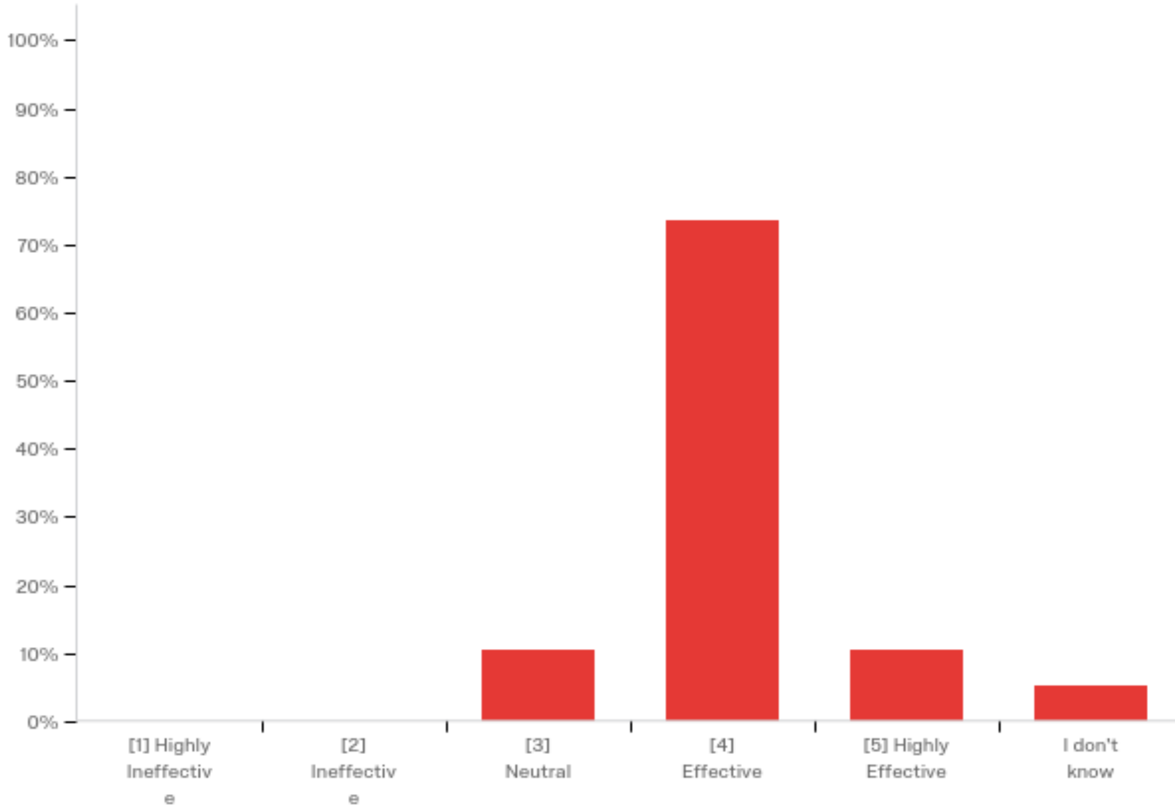
28. We have the right number of systems engineers on my project or program.



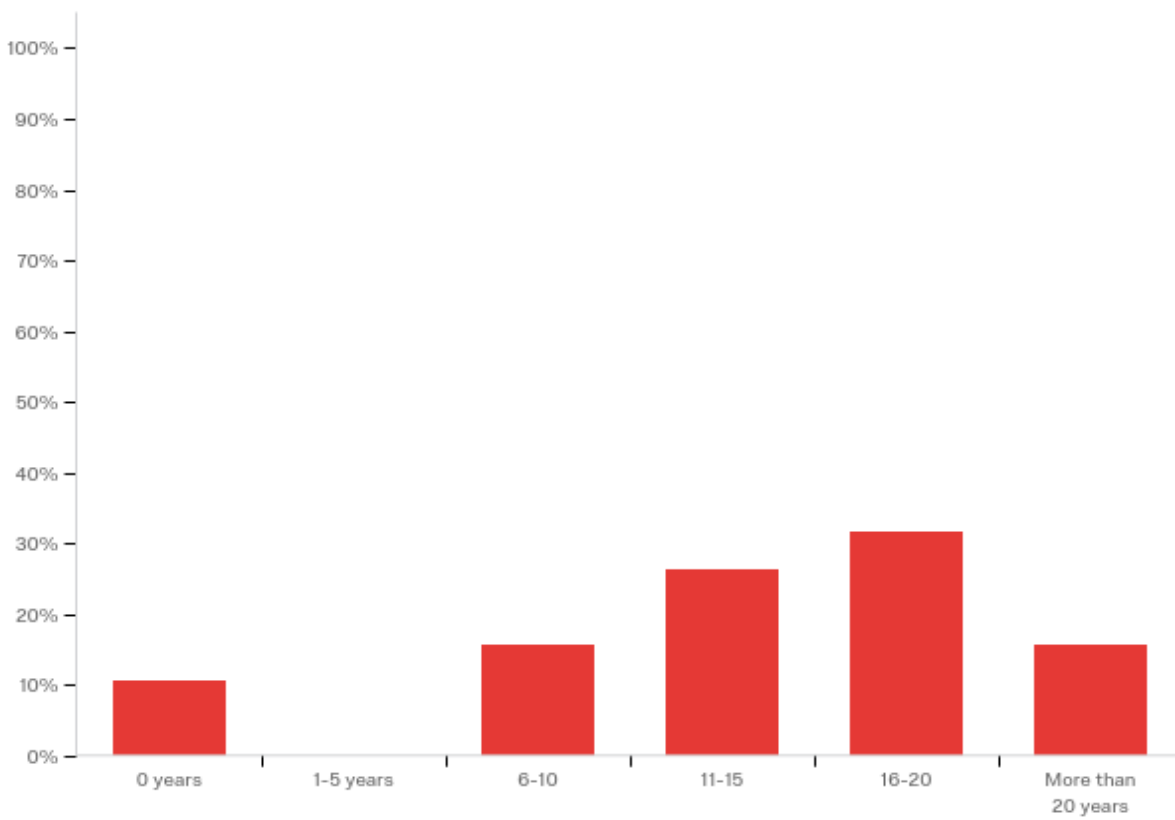
29. Our systems engineers have the skills required to succeed.



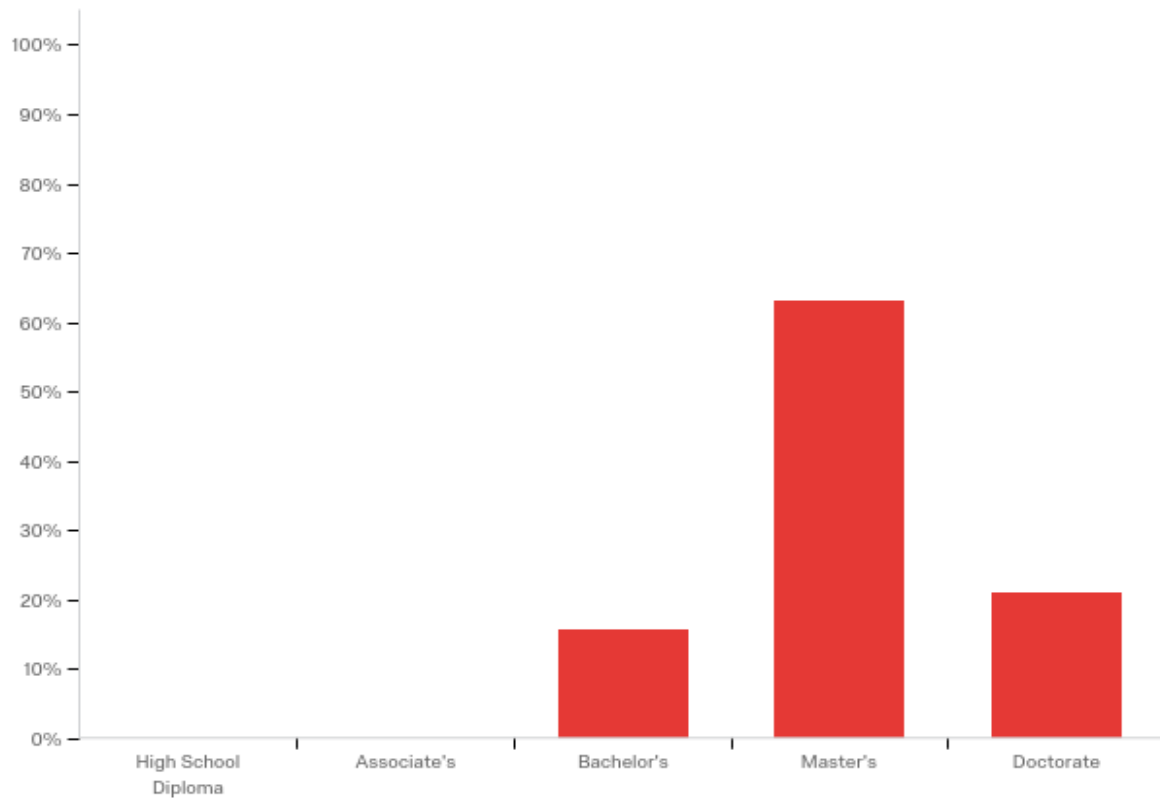
30. Overall, how effective is systems engineering here?



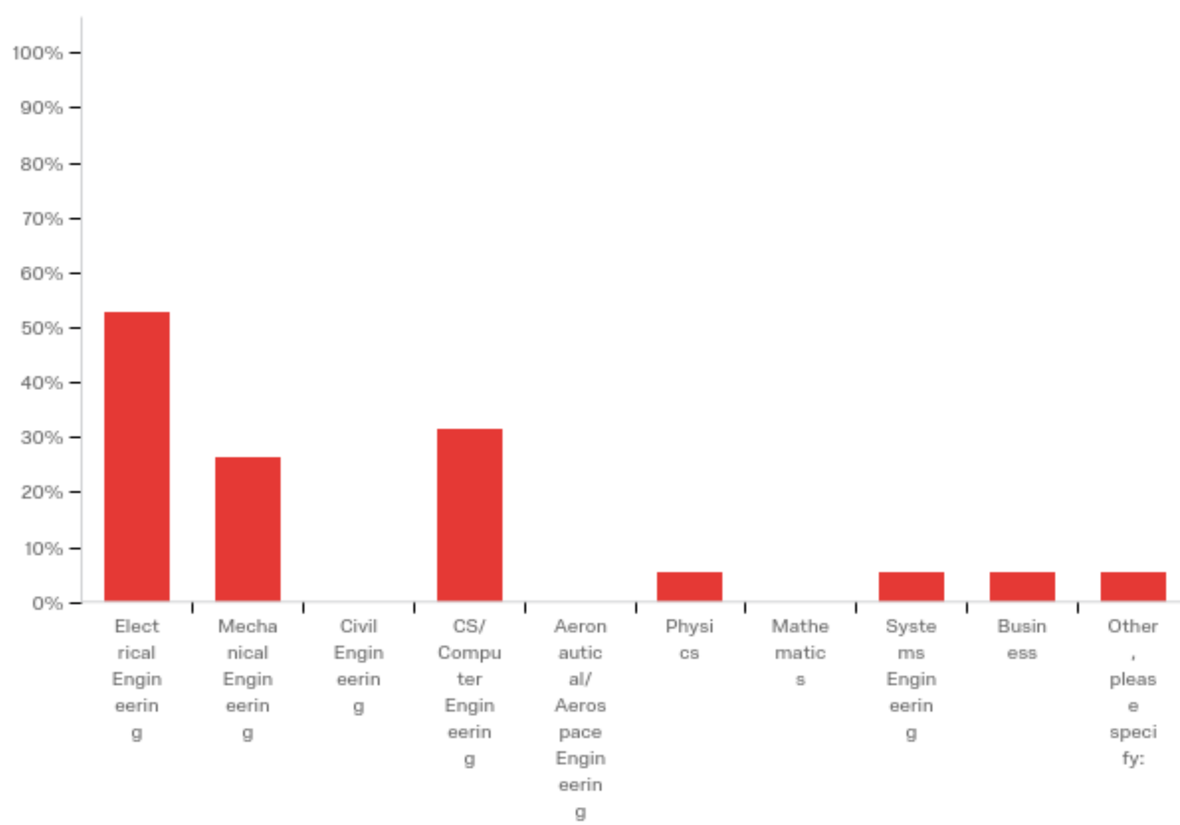
55. Experience in systems engineering:



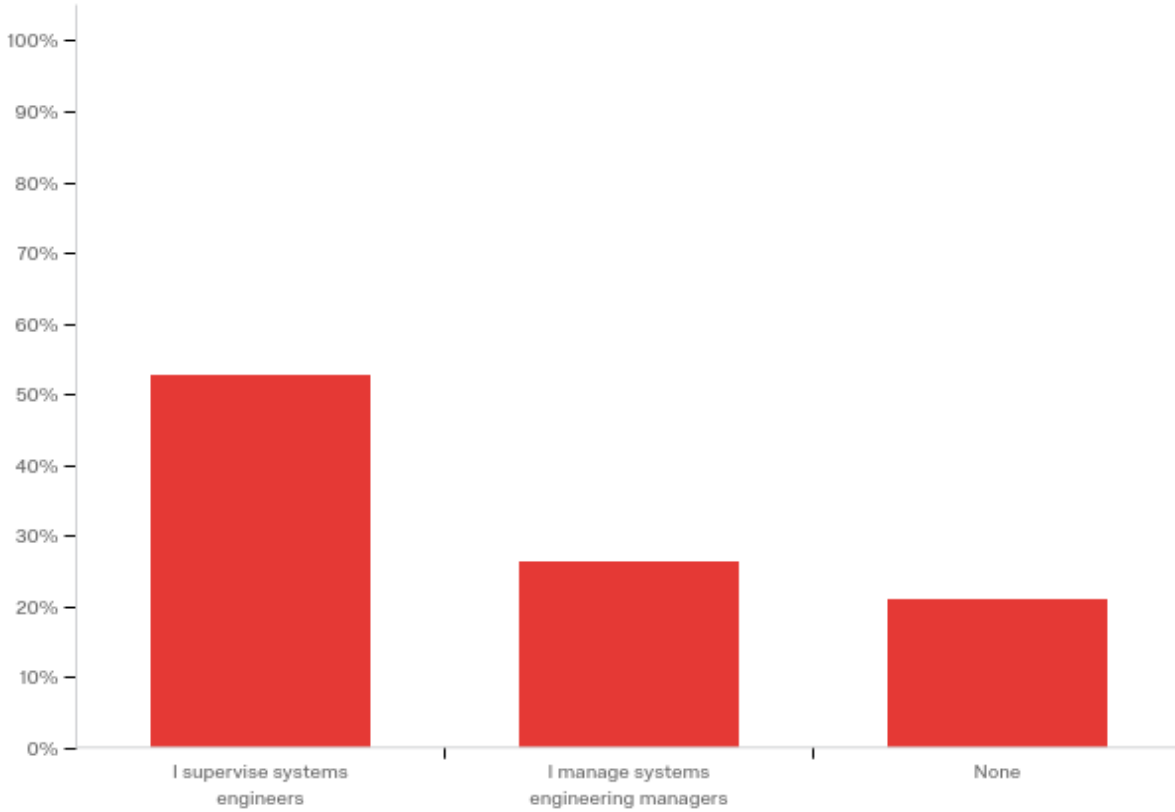
57. What is the highest level of school you have completed or the highest degree you have received?



58. Fields of study:



60. If you manage other people, are they systems engineers?



HELIX

CALL FOR PARTICIPATION

BENEFITS FROM PARTICIPATING IN HELIX

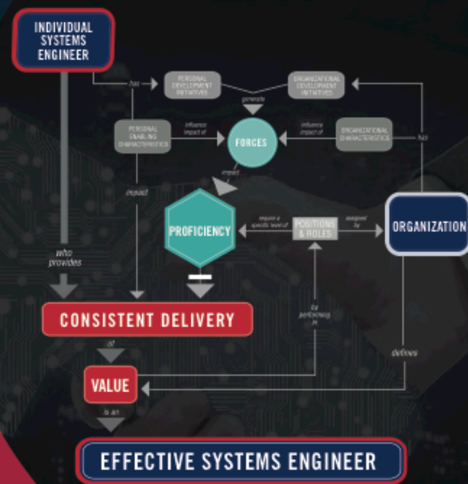
What makes systems engineering effective where you work?

How do your skills map to career paths in your industry?

How does your skillset align with your organization's view of systems engineering?

How does your organization foster effective systems engineering and effective systems engineers?

We need your insights to build experience-based models of effective systems engineering workplaces



HOW CAN I PARTICIPATE IN HELIX?

Atlas provides a framework for examining the

There are many ways to participate:

For individuals:

- Online survey (just scan QR Code below)
- Proficiency and career path self assessments

For organizations:

- Organizational site visits – in-depth analysis and insights into your organization's approach to systems engineering

SINCE 2012, THE HELIX PROJECT HAS INVESTIGATED WHAT MAKES SYSTEMS ENGINEERS EFFECTIVE. THIS WORK CULMINATED IN ATLAS: THE THEORY OF EFFECTIVE SYSTEMS ENGINEERS. THE HELIX TEAM HAS EXPANDED THE RESEARCH TO LOOK MORE CLOSELY AT THE ORGANIZATIONAL FACTORS THAT INFLUENCE SYSTEMS ENGINEERING AS A DISCIPLINE AND THE DELIVERY OF EFFECTIVE SYSTEMS ENGINEERING CAPABILITY. 363 INDIVIDUALS FROM 23 ORGANIZATIONS HAVE PARTICIPATED TO DATE.

SYSTEMS ENGINEERING RESEARCH CENTER