SYSTEMS ENGINEERING
Research Center

Extending *Atlas* to Non-Defense Systems Engineers and to Classic Engineers

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We thank all former members of the Helix research team whose contributions have shaped our research over the years as well as our transcriber, Ms. Mary Ratliff.

– The Helix Team

EXECUTIVE SUMMARY

Beginning in January 2015, the Helix team collected data and conducted analyses to extend the *Atlas* theory of effective systems engineers beyond the defense business sector as well as to adjacent disciplines. The team conducted interviews with project and program managers and 'classic' engineers such as electrical, software, and mechanical engineers. The team investigated whether personnel in these other disciplines had the same characteristics as systems engineers, and where, when, and why these characteristics differed. By looking outside the defense sector to organizations that focus on healthcare, transportation, telecommunications, and information technology systems, the Helix team investigated how the characteristics and roles of systems engineers varied across several different domains and lifecycles.

Atlas was found to be highly relevant to systems engineers outside of the defense sector. This was the perspective of the systems engineers in other business sectors, and by their peers as well. Outside of systems engineering, individuals in related disciplines felt that many aspects of *Atlas* were applicable to themselves, or would be applicable with some tailoring. (See Section 3 for a summary of version 0.5 of *Atlas*). Briefly:

- The definition of effectiveness found in *Atlas* – *an individual systems engineer is effective when she consistently delivers value* – is applicable to systems engineers across domains. Non-systems engineers agreed that this definition was generic enough to apply to themselves as well; provided that "value" was defined appropriately for their discipline, position, and organization.
- The proficiency model of *Atlas* is reasonable and comprehensive for systems engineers outside of the defense sector. For individuals in other disciplines, many of the proficiencies are relevant. Though their importance and relevance were generally seen as less critical early in the careers of project managers or classic engineers, several proficiencies were seen as critical to the maturation of senior individuals within other disciplines as well. *Math/Science/General Engineering* skills were more highly valued by classic engineers throughout their careers; *Technical Leadership* skills were more emphasized by project managers. However, individuals in all fields agreed that for senior individuals in these disciplines, *Technical Leadership*, *Interpersonal Skills*, and *SE Mindset* were critically important. Of course, the proficiency model would have to be tailored to be fully applicable to additional disciplines.
- There is overlap between value for leaders in classic engineering and project management disciplines and for systems engineers. Though their scopes differ, they often stated that they provide similar value in terms of supporting integration, big picture, and enabling teams.

In general, organizations outside of the defense sector used different business models and worked on different types of systems – for example, developing systems with much shorter lifecycles – than seen in the defense sector. These different approaches and lifecycle models can provide more opportunities for systems engineers to experience the breadth of systems engineering activities across the lifecycle; this was identified in *Atlas* as critical for the maturation of systems engineers. These differences provide additional opportunities for systems engineers to grow and mature more quickly.

1 INTRODUCTION

In 2012, the Systems Engineering Research Center (SERC), a US Department of Defense (DoD) University Affiliated Research Center (UARC), launched the Helix Project to investigate the "DNA" of systems engineers, beginning with those who work in the defense community. The US Deputy Assistant Secretary of Defense for Systems Engineering (DASD(SE)), the International Council on Systems Engineering (INCOSE), and the Systems Engineering Division of the National Defense Industrial Association (NDIA-SED) jointly sponsor Helix. Helix is a multi-year longitudinal research project, which is gathering data from many organizations through a combination of techniques, including interviews with systems engineers, self-assessments by systems engineers and their peers, and career path analyses.

Initially, Helix gained traction by interviewing systems engineers directly and focusing exclusively on systems engineers currently working in the defense sector, whether in government or industry. In 2014, the Helix team published *Atlas 0.25*, a theory of effective systems engineers – a set of observations and principles that can be used to explain and predict how and why systems engineers perform effectively, delivering value to the organizations for which they work. (Pyster et al. 2014) In December 2015, *Atlas 0.5* was published, providing insights into key variables that impact a systems engineer's effectiveness and how these variables change and influence effectiveness over time. (Pyster et al. 2015)

In 2015, the Helix team also began exploring the applicability of *Atlas* to new populations. The team explored the themes of *Atlas* with individuals and organizations outside the defense sector, as well as with peers and internal customers of systems engineers, in order to understand how applicable *Atlas* is in these communities, and how insights from these communities could and should influence the maturation of *Atlas* going forward. This report reflects that work.

1.1 BACKGROUND

An improved engineering capability is a recognized DoD science and technology priority, and the SERC is well positioned to make advances towards this priority through research in systems engineering. There is significant interest in DoD, as well as in Congress, in ensuring that DoD can characterize and manage its systems engineering workforce. It is also critical to have a baseline understanding of the systems engineering workforce to determine the impact of SERC and other DoD human capital efforts to improve that workforce. Developing an understanding of the systems engineering workforce is therefore seen as a way for DoD to determine how that workforce could better support the acquisition of defense systems, as well as a way to assess the specific impact of efforts to improve the SE workforce, such as recruiting and retention programs.

When it began, the aim of the Helix project was to answer three research questions, which had never been examined with a significant, systematic effort across the defense community:

- What are the characteristics of systems engineers?
- How effective are systems engineers and why?
- What are employers doing to improve the effectiveness of their systems engineers?

Related areas of concern included how different the characteristics of systems engineers are as perceived by other key personnel on projects such as program/project managers and classic engineers, and whether the findings from the defense community would hold true in other domains. With the publication of *Atlas 0.25* in 2014, the Helix team had a foundation that could be used to begin understanding these relationships. This exploration also had some minor impacts on the evolution of

Atlas 0.5, as reported in (Pyster et al. 2015).

1.2 REPORT STRUCTURE

This report provides insights into how *Atlas* applies to systems engineers outside of the defense sector and to their peers – program/project managers and classic engineers, such as electrical, mechanical, and software engineers – both within and outside of the defense sector. This report is structured into eleven sections:

- Section 2 provides the methodology for the work done and explains where the generic Helix methodology described in (Pyster et al. 2015) was altered to address the expanded scope;
- Section 3 provides a summary of *Atlas 0.5* for reference; additional details can be found in (Pyster et al. 2015);
- Sections 4-9 examines the extended sample population and compares it to the original Helix sample population, using *Atlas* as the framework for that comparison; each section references a different aspect of *Atlas*;
- Section 10 summarizes the key findings and recommendations based on the expanded scope; and
- Section 11 describes the future directions planned for the Helix project in 2016.

Though this report does include a summary of *Atlas 0.5*, it does not detail all of the theory of effective systems engineers. To understand this in depth, refer to (Pyster et al. 2015).

2 HELIX METHODOLOGY

The basic methodology used for this work is the same as for the overarching Helix project, as described previously in (Pyster et al. 2013), (Pyster et al. 2014), and (Pyster et al. 2015). Helix is primarily a qualitative study, with the primary means of data collection being face-to-face interviews. From 2012 to 2013, the Helix team focused on a mixed-methods approach (Creswell and Plano 2011), combining the development of basic research questions with a grounded theory approach. Grounded theory was developed in the social sciences as a method for developing theory that is grounded in data that is systematically gathered and analyzed. (Goulding 2002) This approach allows the data itself to drive points of further inquiry, guide categorization, etc.; rather than starting analysis with an existing framework, all of the data is reviewed holistically and any potential areas of interest are coded. Over time, patterns emerge and these guide further data collection and analysis. The development of driving research questions, as identified in Section 1, make the Helix project mixed method as opposed to pure grounded theory.

2.1 OVERARCHING RESEARCH PROCESS

Data for this research was obtained primarily through interviews with systems engineers from the U.S. Department of Defense (DoD) and corporations in the defense industrial base (DIB). The overall approach to the project can be seen in Figure 1.

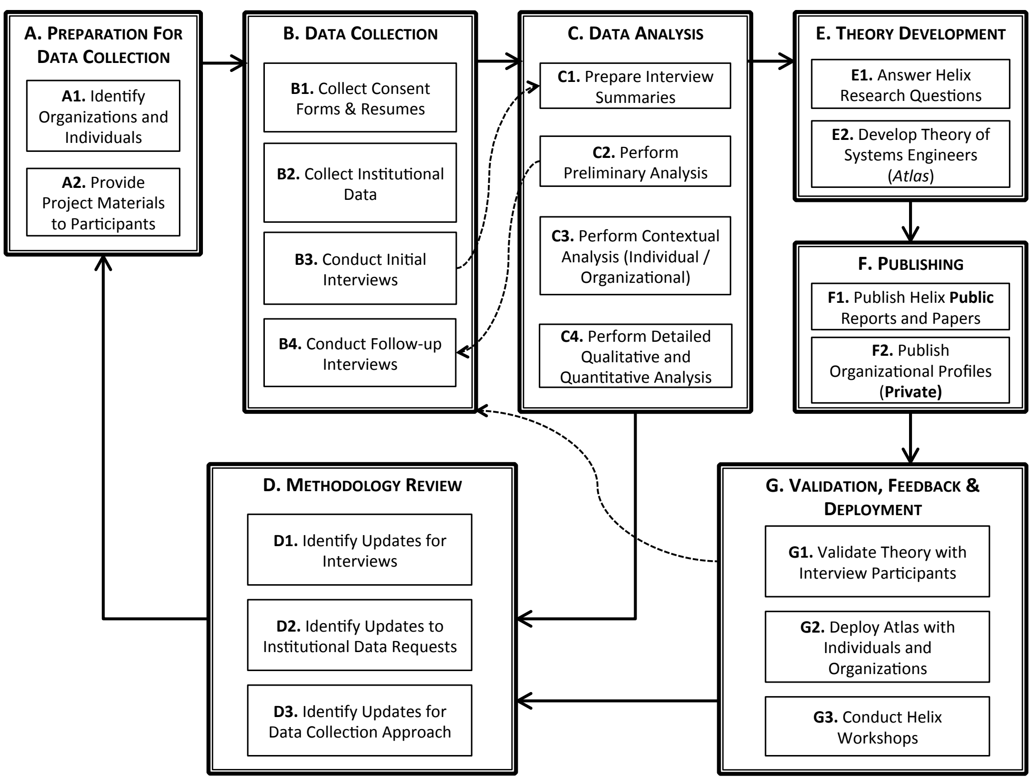

Figure 1. Helix Research Process

At the highest level, the research approach consists of a 7-step iterative process:

A. Preparation for the interview cycle, which includes review and revisions of the methods and tools;

B. Collection of data, which occurs in multiple parts; organizational data and some basic demographics for individuals are collected prior to interviews; data is collected during initial interviews and again during follow-up interviews and validation interviews;

C. Analysis of the data to identify patterns in response, particularly common experiences, what is learned through these experiences, and how these experiences particularly support performance in a particular systems engineering role;

D. Comparison of the findings to the original research questions to determine which insights are applicable, which information needs to be pursued, and how this will impact the methodology;

E. Development of *Atlas*, the theory of effective systems engineers;

F. Publication of results, a combination of periodic reports on the Helix project, conference papers and presentations, and peer-reviewed journal articles; and

G. Validation of results through additional interviews with new subjects, follow up interviews with existing subjects, and community outreach such as the Helix workshop.

This process guided the Helix work outside of the defense sector and with systems engineers' peers and internal customers as well. For additional details on the individual steps of this methodology, please refer to (Pyster et al. 2015).

2.2 Methodological Changes for Investigating Classic Engineers

Although the overarching methodology and process for Helix remained consistent for the work described in this report, there were some changes to the approach, as described below.

2.2.1 Step A: Identify Interview Subjects

As stated above, one objective for this additional branch of the Helix project was to expand the scope beyond just systems engineers in order to understand how the findings about systems engineers related to other disciplines, specifically project management and classic engineering disciplines, such as electrical, mechanical, and software.

To that end, the Helix team interviewed 107 individuals specifically to support this expansion – some inside the defense sector and some outside defense as described in Section 2.3.1, bringing total Helix participation up to 288 individuals. These individuals provided insights on how *Atlas* applied to them as individuals, their views on how *Atlas* applied to their discipline(s), and their views of systems engineers and systems engineering based upon their own experiences.

2.2.2 Step A: Coordinate with Organizations

As also stated previously, another objective for this additional work was to expand the scope of work outside of the traditional defense sector. To that end, 9 organizations were added to the Helix data set, bringing the total number of participating organizations to 20 since the Helix project began. The 9 added organizations were from government as well as industry; the industrial focus areas included transportation, healthcare, information technology, and telecommunications.

In order to support the breadth of individuals and domains desired, the Helix team also invited individuals to participate independently, instead of as a cohort within an organization. This enabled a wider variety of individuals to participate and gave us insights into more organizations.

2.2.3 Steps B and D: Interview Format

Primarily with the defense sector systems engineers, initial interviews were conducted face-to-face individually or in small groups of two or three people. When working with systems engineers outside of the defense sector, that practice has largely persisted. However, particularly in working with systems engineers' peers and with the internal customers of systems engineers, a larger group format was found to be more effective. These larger groups generally ranged from four to seven individuals. In addition, the format was further changed from a semi-structured interview to a more focused discussion with some detailed instruments that were provided for individuals to perform self and peer assessments around the elements of *Atlas*. This enabled the Helix team to work with a larger group in a more focused way, and maximized the effectiveness of site visits.

In addition, a small number of individuals volunteered to be interviewed directly, without the Helix team coordinating through their organizations. Traditionally, the Helix team has worked with a cohort of a dozen to two dozen individuals from a single organization. Working with individuals directly provided the team insights into a greater variety of organizations, although it did limit the ability of the team to make organization-related insights.

2.2.4 Step C: Comparative Analysis

The Helix team added layers of coding to its analysis, particularly around the types of individuals who provided interview data, and around the organizations in which those individuals worked. Previously, nearly all interview participants had been systems engineers. Characterizing interview data by the type of position an interviewee holds – project manager, classic engineer, or systems engineer – then became important for the team to conduct comparative analysis of these populations and their views. Likewise, adding layers for the organizations enabled the team to compare findings across industries and other organizational characteristics, to determine where insights from the defense community were unique and where they might be more universal.

2.2.5 Step D: Updates to Questions

As could be expected, the questions used to guide the semi-structured Helix interviews had to be updated to accommodate working in new business sectors and with individuals from multiple disciplines. This included changing the terminology because systems engineering terms as discussed in the defense community are often not understood outside that community. This was part of the iterative methodology review illustrated in Step F of Figure 1.

2.2.6 Steps E and G: Applicability and Validation of Atlas

Because *Atlas 0.25* was developed prior to the start of this new data collection, one of the primary benefits of expanding the sample was the ability to gain feedback on the applicability of *Atlas* to new areas and to validate existing findings. Each interview introduced new individuals to *Atlas* and gave them the opportunity to identify which aspects were relevant to their organizations and careers, which were less relevant, and explain why this was the case. In addition, they also provided feedback on existing findings. For example, systems engineers in the defense industry had provided detailed feedback on what they believed constituted "value"; these new interviewees were asked to identify the values that they believe systems engineers bring to their own organizations.

2.3 DATASET

The primary source of data for Helix research is face-to-face semi-structured interviews with participants at their place of work. Additional information about the participant and the organization was also collected as available. Occasionally, these interviews were conducted via telephone rather than in person. Helix also gained access to the application data for the INCOSE Systems Engineering Professional (SEP) certification program through an agreement with INCOSE.

2.3.1 HELIX INTERVIEW DATA

From June 2013, when Helix conducted its first site visit for data collection, until November 2015, a total of 288 participants were interviewed from 20 organizations. From this sample, data from 181 individuals was used to generate *Atlas 0.*5 while an additional 107 individuals from 9 organizations were specifically targeted to help address the expanded questions of the differences between defense and non-defense organizations and the applicability of *Atlas* to those outside of systems engineering. *The analysis surrounding these 107 individuals is referred to as the* ***expanded dataset*** *throughout this report.*

Typically, 2 or 3 members of the Helix team interviewed anywhere from 1 to 6 participants in a single interview session. Interview participants, if willing, also provided their resumes with details about their educational background, work experiences, and any other information they wished to provide.

Transcripts were created when audio recording was permitted; and when not permitted, summaries were prepared from notes taken during the interviews. The data that was incorporated into *Atlas 0.5* was limited to a subset of interviewees from DoD and DIB organizations. (Pyster et al. 2015)

2.3.2 DEMOGRAPHICS OF INTERVIEW POPULATION

Among the 288 participants across all Helix interviews, 78% were male and 22% were female. For the 107 individuals whose interviews are in the expanded dataset, that ratio was 71% male and 29% female.

The Helix team created a detailed rubric for understanding the seniority of systems engineers. That rubric was validated with systems engineers' normalized self-assessments of their own seniority. (Pyster et al. 2015) The team did not have sufficient data to create seniority rubrics for the individuals in each of the other disciplines reported here. Therefore, the team simply recorded the self-assessments of these individuals. A comparison of the seniority profiles of the systems engineers in the original and expanded datasets can be found in Figure 2.

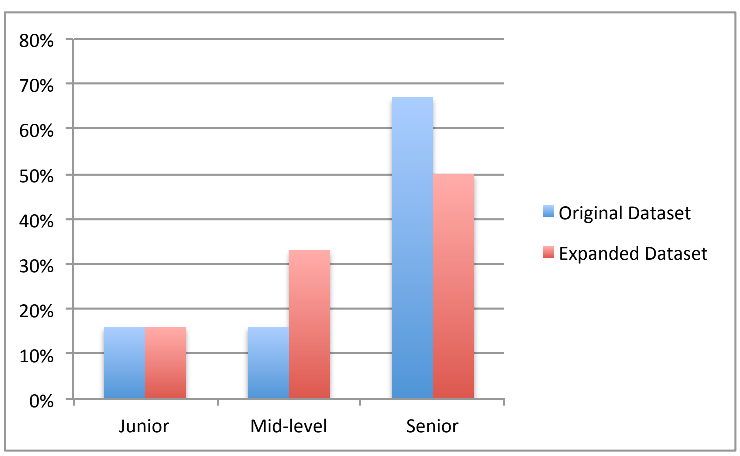

Figure 2. Seniority of Helix Interview Population

Among the 20 organizations that have participated in Helix interviews, 11 were from the DoD or DIB; the other 9 were from healthcare, transportation, IT, and telecommunications. Note that this does not mean that the organization focused *only* on these areas, but rather the segment of the organization that participated in Helix was focused on these areas. Figure 3 provides an overview of the percentage of individuals from each of these sectors or domains in the expanded data (of the 107 total). In Figure 3, blue represents the original dataset analyzed for the creation of *Atlas 0.5* and red represents the dataset for this expansion.

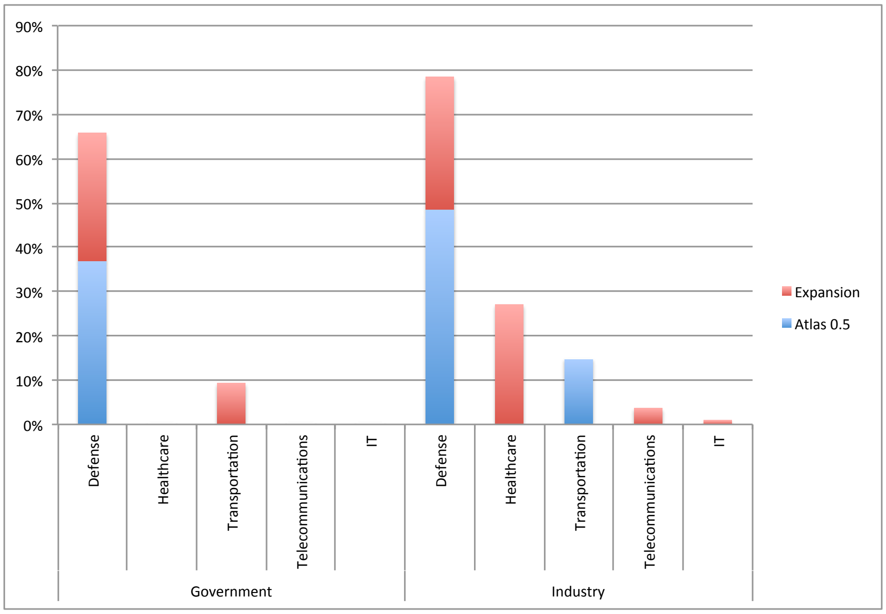

Figure 3. Breakdown of Current Sample (N=107) by Domain across Government and Industry

In terms of the types of positions filled by these individuals, the analysis was broken down according to discipline: systems engineering (SE), program/project management (PM), and classic engineering disciplines including electrical (EE), mechanical (ME), software (SwE), and "other" engineering. Figure 4 provides an overview of the breakdown of the sample along these lines (N=107). Of the expanded interviewees, 77% were systems engineers and 23% were non-systems engineers. Over half of the non-systems engineers in the expansion were project managers and 45% were classic engineers. The "other" engineers in the sample are engineers focused on a specific technology such as radar or ultrasound.

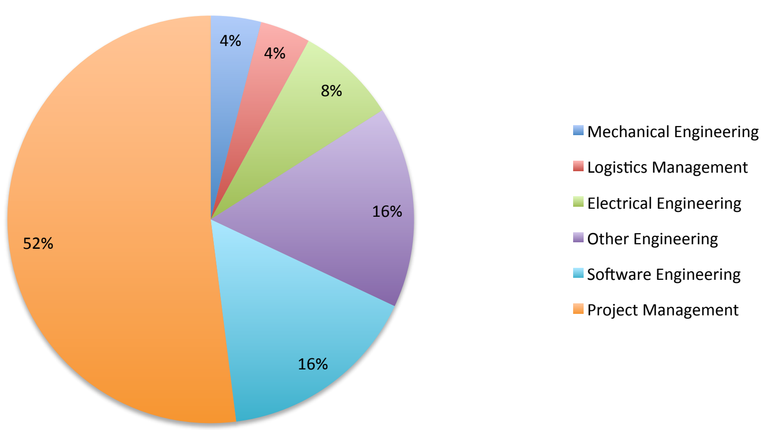

Figure 4. Disciplines of Non-Systems Engineers in The Expanded Sample

The percentages in Figure 4 need some interpretation. At times, individuals were identified as belonging to a discipline by their organizations. However, when they were asked whether or not their positions were in systems engineering, many gave responses such as, "well, I do a mix of things, but I definitely perform some systems engineering activities." The individuals reflected in Figure 4 (23% of the expanded dataset) *self-identified* as non-systems engineers. There were other individuals identified as non-systems engineers by their organizations who stated in their interviews that although their titles reflect a different position – such as mechanical engineering – their primary responsibilities really fell more under systems engineering, and therefore, they self-identified as systems engineers.

2.3.3 INCOSE SEP Applicants

INCOSE provides three different levels of SEP certification: Associate (ASEP), Certified (CSEP), and Expert (ESEP). Applicants from all over the world seeking INCOSE certification apply for the appropriate level based on their systems engineering experiences, knowledge, and accomplishment. In addition to the interviews, the Helix team also examined the applications of 2504 applicants to the INCOSE Certified Systems Engineer Professional program. The overarching findings on the INCOSE dataset are provided in (Lipizzi et al. 2015) and (Jauregui et al. 2016, submitted).

Initially, the team hoped that the INCOSE data would be extremely valuable for understanding non-systems engineers who grew to become systems engineers. However, upon closer examination of the data, applications were primarily focused on *systems engineering* positions, and did not often include earlier positions such as mechanical, software, or electrical engineer. In fact, that data was so sparse that no reasonable conclusions could be drawn.

The team also reviewed the organizations that CSEP applicants cited, in hopes of drawing conclusions based on differences between defense and non-defense organizations. This proved to be more difficult than expected for several reasons. First, with 2504 applications, there were many organizations that were not familiar to the team and required research about whether the organization was "defense" or "non-defense". With hundreds of individual organizations, this proved a daunting task, particularly for non-US companies. Second, there were many one-off organizations – organizations from which only one or two individuals had applied; which implied that any effort to study each individual organization impacted only a few individuals in the sample. Finally, even well-known organizations often had both defense and non-defense businesses. For these organizations, the only way to determine whether the organization was "defense" or "non-defense" was to try to glean the information based on the position description.

For all of these reasons, the team made the decision to scope the analysis down to "ChiefX" systems engineers in the sample; these were individuals identified by the team as equivalent to Chief Systems Engineers as reported in (Jauregui et al. 2016, submitted). Because these individ have reached the pinnacle of a technical systems engineering career, it seems reasonable to draw insights from their careers. This information is reported in Sections 7.1.1 and 7.3.2, below.

3 SUMMARY OF *ATLAS* 0.5

According to Merriam-Webster, a theory is a set of general principles or ideas relating to a particular subject (2014). *Atlas* is a set of general principles and ideas that relates to the subject of what makes systems engineers effective and why. In doing so, *Atlas* also provides insights into how individuals can develop into effective systems engineers throughout their careers and what organizations can do to support this development. This section is a summary of the information presented in (Pyster et al. 2015).

3.1 OVERVIEW

The overview of *Atlas* in the context of an individual systems engineer employed in an organization is captured in the systemigram illustrated in Figure 5. A systemigram consists of nodes that contain noun phrases, links that contain verb phrases, and is to be read as sentences along the direction of the arrows. The primary sentence is read from the top left node to the bottom right node and presents the main theme of the systemigram. In the ensuing discussions, sentences to be read in the systemigram are italicized, where nodes are represented in square brackets.

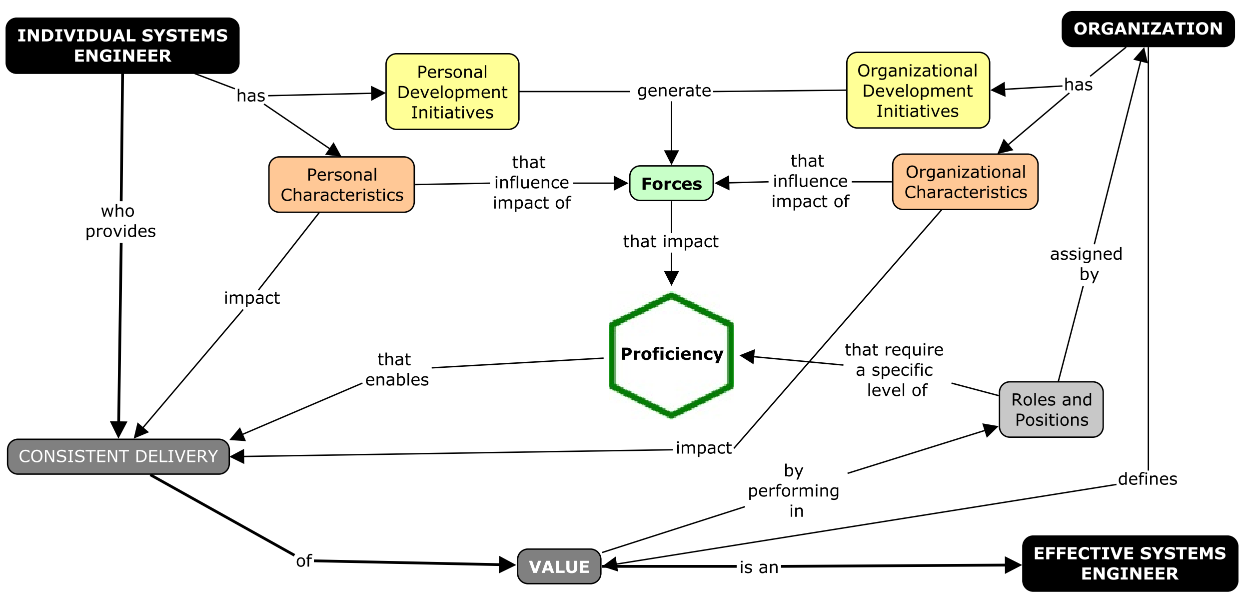

Figure 5. *Atlas* Overview

From Figure 5, it can be seen that the main theme of *Atlas* is: '*[Individual Systems Engineer] who provides [Consistent Delivery] of [Value] is an [Effective Systems Engineer]*'. This fundamental definition of an effective systems engineer hinges on *[Value]*, and it can be seen that '*[Organization] defines [Value]*'. Therefore, it is on the organization to define the value that the systems engineer is expected to provide. Further, the individual systems engineer provides '*[Value] by performing in [Roles and Positions] assigned by [Organization]*'. Therefore, it is again on the organization to establish the position of the systems engineer in terms of roles and responsibilities, keeping in mind that '*[Positions] require a specific level of [Proficiency] that enables [Consistent Delivery] of [Value]*'.

The core of *Atlas* is the proficiency of the individual systems engineer – what it is, and how it can be improved. '*[Individual Systems Engineer] has [Personal Development Initiatives]*' and '*[Organization] has [Organizational Development Initiatives]*'; together, they '*generate [Forces] that impact [Proficiency]*'. At the same time, '*[Individual Systems Engineer] has [Personal Characteristics] that influence the impact of [Forces]' and '[Organization] has [Organizational Characteristics] that influence the impact of [Forces]'* – these forces may have a positive or a negative influence. Further, both personal enabling characteristics and organizational characteristics '*impact [Consistent Delivery] of [Value]*'; again, the impact can be positive or negative. Amidst all these influences and impacts, the challenge for the individual systems engineer and the organization is to improve the '*[Proficiency] that enables [Consistent Delivery] of [Value]*' to the organization.

3.2 VALUES SYSTEMS ENGINEERS PROVIDE

In *Atlas 0.5*, the Helix team identified six key values that systems engineers in the defense sector provide with many enabling values that support the achievement of these key values. The key values identified include:

- Keeping and maintaining the system vision;
- Enabling diverse teams to successfully develop systems;
- Managing emergence in both the project and the system;
- Enabling good technical decisions at the system level;
- Supporting the business cases for systems; and
- Translation of technical jargon into business or operational terms and vice versa.

The key skills that support delivery of these values are detailed in (Pyster et al. 2015).

3.3 PROFICIENCY OF SYSTEMS ENGINEERS

The *Atlas* proficiency model consists of six proficiency areas based on the Helix interview data, as shown in Figure 6 below.

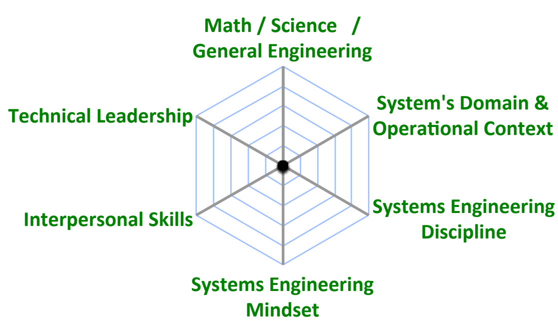

Figure 6. Proficiency Areas for Systems Engineers

1. ***Math/Science/General Engineering:*** Foundational concepts from mathematics, physical sciences, and general engineering;
2. ***System's Domain & Operational Context****:* Relevant domains, disciplines, and technologies for a given system and its operation;
3. ***Systems Engineering Discipline***: Foundation of systems science and systems engineering knowledge;

4. ***Systems Engineering Mindset***: Skills, behaviors, and cognition associated with being a systems engineer;

5. ***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

6. ***Technical Leadership***: Skills and behaviors associated with the ability to guide a diverse team of experts toward a specific technical goal.

Proficiency areas 1 to 3 may be considered the more 'hard' or technically based skills, while proficiency areas 4 to 6 may broadly be considered 'soft skills'. Development and evaluation of soft skills is addressed by the disciplines of psychology, social sciences, and management sciences. The six proficiency areas in *Atlas* are further divided into *categories* and, in some cases, into *topics*, as shown in Figure 6. Each proficiency area is outlined in Table 1 and further elaborated in the *Atlas 0.5* report. (Pyster et al. 2015)

Table 1. Atlas Proficiency Areas, Categories, and Topics

Area	Category	Topic
1. Math / Science / General Engineering	**1.1.** Natural Science Foundations	
	1.2. Engineering Fundamentals	
	1.3. Probability & Statistics	
	1.4. Calculus & Analytical Geometry	
	1.5. Computing Fundamentals	
2. Systems' Domain & Operational Context	**2.1.** Relevant Domains	
	2.2. Relevant Technologies & Systems	
	2.3. Relevant Disciplines	
	2.4. Familiarity with System's Concept of Operations (ConOps)	
3. Systems Engineering Discipline	**3.1.** Lifecycle	3.1.1 Lifecycle Models; 3.1.2 Concept Definition; 3.1.3 System Definition; 3.1.4 System Realization; 3.1.5 System Deployment & Use; 3.1.6 Product & Service Life Management
	3.2. Systems Engineering Management	3.2.1 Planning; Risk Management; 3.2.2 Configuration Management; 3.2.3 Assessment & Control; 3.2.4 Quality Management
	3.3. SE Methods, Processes, & Tools	3.3.1 Balance & Optimization; 3.3.2 Modeling & Optimization; 3.3.3 Development Process; 3.3.4 Systems Engineering Tools
	3.4. System Complexity	
4. Systems Engineering Mindset	**4.1.** Big-Picture Thinking	
	4.2. Paradoxical Mindset	4.2.1 Big-Picture Thinking and Attention to Detail; 4.2.1 Strategic and Tactical; 4.2.1 Analytic and Synthetic; 4.2.1 Courageous and Humble; 4.2.1 Methodical and Creative
	4.3. Flexible Comfort Zone	
	4.4. Abstraction	
	4.5. Foresight & Vision	

Area	Category	Topic
5. Interpersonal Skills	5.1. Communication	5.1.1 Audience; 5.1.2 Content; 5.1.3 Mode
	5.2. Listening & Comprehension	
	5.3. Working in a Team	
	5.4. Influence, Persuasion & Negotiation	
	5.5. Building a Social Network	
6. Technical Leadership	6.1. Building & Orchestrating a Diverse Team	
	6.2. Balanced Decision Making & Rational Risk Taking	
	6.3. Managing Stakeholders and their Needs	
	6.4. Conflict Resolution & Barrier Breaking	
	6.5. Business & Project Management Skills	

3.4 Forces That Impact Proficiency

The three most important forces that significantly impact the proficiency of systems engineers are Experiences, Mentoring, and Education & Training, in that order. These forces are generated by a combination of personal and organizational initiatives. The application of these forces is the primary way by which proficiencies of an individual are developed, as illustrated in Figure 7 below.

In every organization that participated, these forces were identified as relevant, and no additional forces were identified. Program managers and classic engineers also agreed that these were the key forces for their own development.

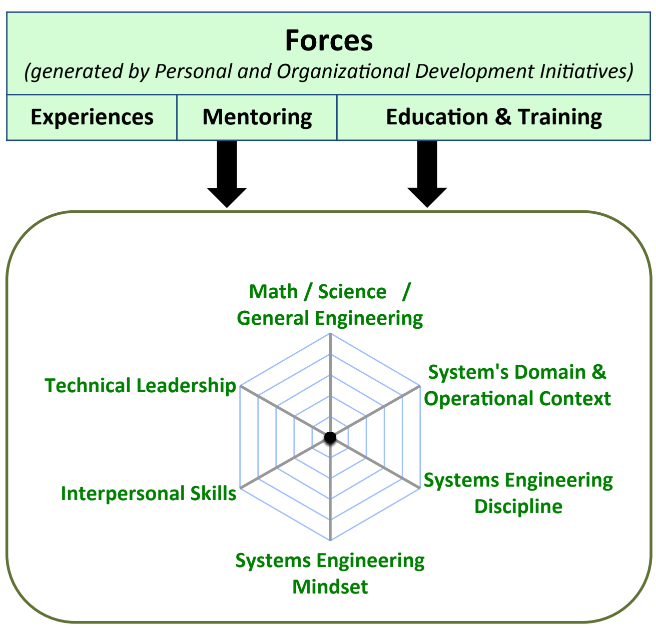

Figure 7. Forces and Proficiency

3.4.1 Experiences

Experiences are considered the most critical force contributing to the development of proficiencies and to the overall growth of systems engineers. However, it is the characterization of these experiences that provides insight into how they impact proficiencies over time. Considering experiences as a force, each of these dimensions contributes to increasing one or more areas of proficiency. Experiences can also impact the personal characteristics of an individual. The analysis of Experiences, as considered in *Atlas*, includes the following characteristics:

- **Relevance:** A 'relevant' position is one that enables a systems engineer to develop the proficiencies critical to systems engineering.
- **Position:** Every systems engineer who is employed at an organization fills a position that is established by the organization; that organization also defines the roles and responsibilities to be performed. Helix considers position as a 'unit of measure' for experience, since most of the characteristics of experience are in the context of the position that is being held. A 'systems engineering' position is one where the individual's primary focus was on systems engineering activities.
- **Chronological Time:** The amount of time spent in any particular position or in performing a role.
- **Number of Organizations:** The number of different organizations that an individual has worked at, not counting internal movement within an organization across departments or divisions, reflects the variety of types of experiences that one may possess.
- **Organizational Sectors:** There are many differences in the general characteristics of an organization based on its sector. In *Atlas*, three organizational sectors are identified: government, industry, and academia.
- **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 Section 3.5, below.
- **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*). (BKCASE Authors 2015)
- **Systems:** There are many aspects to the types of systems on which a systems engineer could work. Working across these different categories provides valuable experience to an individual systems engineer.
    - **Domain:** This is the primary area of application for the systems being worked on. However, there are many domain categorizations; some domains also relate to industry sectors.
    - **Type:** Product systems, service systems, and enterprise systems are three major types of systems, depending on the nature and composition of the system of interest. System of systems is another paradigm in systems engineering, and could be a combination of one or more types of systems.
    - **Level:** A systems engineer could work on various levels of a system: component/element, subsystem, system, and platform or system of systems.

3.4.2 MENTORING

Mentoring (or mentorship) is a relationship between two individuals: a mentor possesses more experience and knowledge and shares these with a mentee for the mentee's personal development. The effectiveness and derived value of the mentoring relationship is dependent on the individuals involved, but is also influenced by the organization which derives value out of a mentoring relationship as well.

Mentoring means different things to different individuals and to different organizations. Commonly, two individuals are involved in a mentoring arrangement: a *mentor* and a *mentee* (also referred to as a protégé). The mentor is usually senior when compared to the mentee in age, experience, and/or expertise. Primarily, the mentor gives and the mentee receives and mentor-mentee interactions typically happen over an extended period of time at varying frequencies.

Mentoring arrangements can either be formal or informal, depending on the level of engagement of the organization in establishing and sustaining the mentoring relationship. In a formal mentoring arrangement, the organization plays an active role in establishing the mentor-mentee relationship, and also lays down guidelines for maintaining that relationship. Usually, organizations require that objectives and expectations for the mentor and the mentee be stated explicitly. The relationship and its progress tend to be monitored by the organization. In an informal mentoring relationship, the participating individuals establish the mentor–mentee relationship by themselves: either a mentor adopts a mentee or a mentee seeks out a mentor, and the relationship is established. Formal objectives or expectations are usually not stated explicitly, but it is considered good practice to establish these in some form at the start of the relationship. The organization plays a less active role in informal mentoring. It is on the mentor and the mentee to establish and drive the relationship.

There are three types of mentoring identified to date: career, technical, and organizational. In career mentoring, the mentor provides advice on career-related issues: helps identify career goals and the paths leading to that goal. The mentor could be from another group or division in the organization. Mentees are also groomed on management and leadership related topics. In technical mentoring, the mentor typically provides advice on the technical details of the system being engineered. The mentor teaches lessons that are typically not found in textbooks and provides crucial insights on technical tools and processes. The mentor also acts as a subject matter expert, answering questions mentees might have on the subject, the system, or the program. In organizational mentoring, the mentor provides information about the organization: its culture, its procedures, and its policies. This is especially critical to a new employee.

3.4.3 EDUCATION AND TRAINING

Education plays two key roles in the development of systems engineers:

- It provides the foundation knowledge to support engineering-related work. Typically, this takes the form of undergraduate education in an engineering discipline, technical field, or physical science.
- Graduate level education is an avenue to develop more advanced skills, explore more in-depth knowledge, and help systems engineers grow as they move through their careers.

In addition to formal academic programs leading to undergraduate and graduate degrees, there are graduate certificates that individuals obtain, in an area that is closely related to their work. Some systems engineers go on to obtain doctoral degrees as well.

Systems engineers typically start their careers after obtaining an undergraduate degree, while graduate degrees may be obtained immediately after an undergraduate program or after a few years of professional work. Any formal degree directly improves proficiency in the relevant areas and categories. Any undergraduate degree in engineering typically provides much of the Math/Science/General Engineering proficiency in addition to the relevant categories under the Systems' Domain & Operational Context proficiency area. Graduate degrees add to relevant proficiencies; much of the formal systems engineering education happens at the graduate level.

While academic programs are typically offered by a university, there are a number of tailored training programs that organizations offer their employees. These training programs are more focused on building specific skills that are required for their work and are typically offered for near-term application. Topics vary widely across organizations, with some training focused on technical aspects of systems development, other training focused on organization-specific approaches and processes, and still other training focused on leadership or interpersonal skills. Each type of training has a role in the development of proficiency.

3.5 Positions and Roles

*A **position** held by an individual is equivalent to a 'title', where the organization defines what roles and responsibilities it entails.* Each position has a variety of characteristics, which align with the characteristics of experiences (See Section 3.4.1), including the length of the position, the types of systems worked on in that position, the roles played, and the aspects of the lifecycle seen.

An individual systems engineer fills a position (or holds a title) in an organization; there are many roles that a systems engineer is expected to perform in that position. *A **role** performed by an individual consists of a specific set of related activities. Atlas* identifies 16 systems engineering roles; typically, a systems engineer performs a combination of these roles while holding a single position. Starting with the 'twelve systems engineering roles' identified by Sheard (1996), Helix added five more to reflect additional roles reflecting Helix data collected during interviews about the activities that systems engineers perform in organizations today. The role of 'Classified Ad' identified by Sheard is not included in *Atlas* because Sheard added it to account for positions often posted in job listings (such as 'Microsoft Systems Engineer'); 'Classified Ad' is not a role that systems engineers, as defined by *Atlas*, actually perform. Table 2 below, describes each of the 16 roles identified in *Atlas*.

Table 2. Roles of a Systems Engineer

#	Role (Abbreviation)	Description
1.	**Requirements Owner** +	Individual who is responsible for translating customer requirements to system or sub-system requirements; or for developing the functional architecture.
2.	**System Designer (SD)** +	Individual who is responsible for owning or architecting the system; common titles may includes chief systems engineer or system architect.
3.	**System Analyst (SA)** +	Individual who provides modeling or analysis support to system development activities, and helps to ensure that the system as designed meets he specification.
4.	**V&V Engineer (VV)** +	Individual who plans and conducts verification and validation activities such as testing, demonstration, and simulation.
5.	**Logistics/ Operations Engineer (LO)** +	Individual who performs the 'back end' of the SE lifecycle, who may operate the system, provide support during operation, provide guidance on maintenance, or help with disposal.

#	Role (Abbreviation)	Description
6.	Glue (GL) +	Individual who is responsible for 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.
7.	Customer Interface (CI) +	Individual who is responsible for coordinating with the customer, particularly for ensuring that the customer understands technical detail and that a customer's desires are, in turn, communicated to the technical team.
8.	Technical Manager (TM) +	Individual who is responsible for controlling cost, schedule, and resources for the technical aspects of a system; often someone who works in coordination with an overall project or program manager.
9.	Information Manager (IM) +	Individual who is responsible for the flow of information in a system development activity; specific activities may include configuration management, data management, or metrics.
10.	Process Engineer (PE) +	Individual who is responsible for the systems engineering process as a whole; who also likely has direct ties into the business.
11.	Coordinator (CO) +	Individual who is responsible for coordination amongst a broad set of individuals or groups who help to resolve systems related issues.
12.	Systems Engineering Evangelist (EV) +++	Individual who promotes the value of systems engineering to individuals outside of the SE community - to project managers, other engineers, or management.
13.	Detailed Designer (DD) ++	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.
14.	Organizational/ Functional Manager (MG) ++	Individual who is responsible for the personnel management of systems engineers or other technical personnel in a business – not a project or program – setting.
15.	Instructor/ Teacher (IN) +++	Individual who is responsible for providing or overseeing instruction of SE discipline, practices, processes, etc.
16.	Program/Project Manager (PM) ++	Individual who performs program or project management activities; who is not directly responsible for the technical content of a program, but works closely with technical experts and other systems engineers.

+ Roles identified by Sheard (1996) [Roles 1 – 11 above]

++ Roles identified by Helix [Roles 13, 14, and 16 above]

+++ Roles recommended in Sheard (2000) and adopted by Helix based on the data available [Roles 12 and 15 above]

3.6 Characteristics

As illustrated in Figure 8, there are personal and organizational characteristics that influence both the way that forces help proficiencies grow and which forces and individual might have exposure to. Figure 8 provides additional detail on the specific characteristics identified in *Atlas 0.5*.

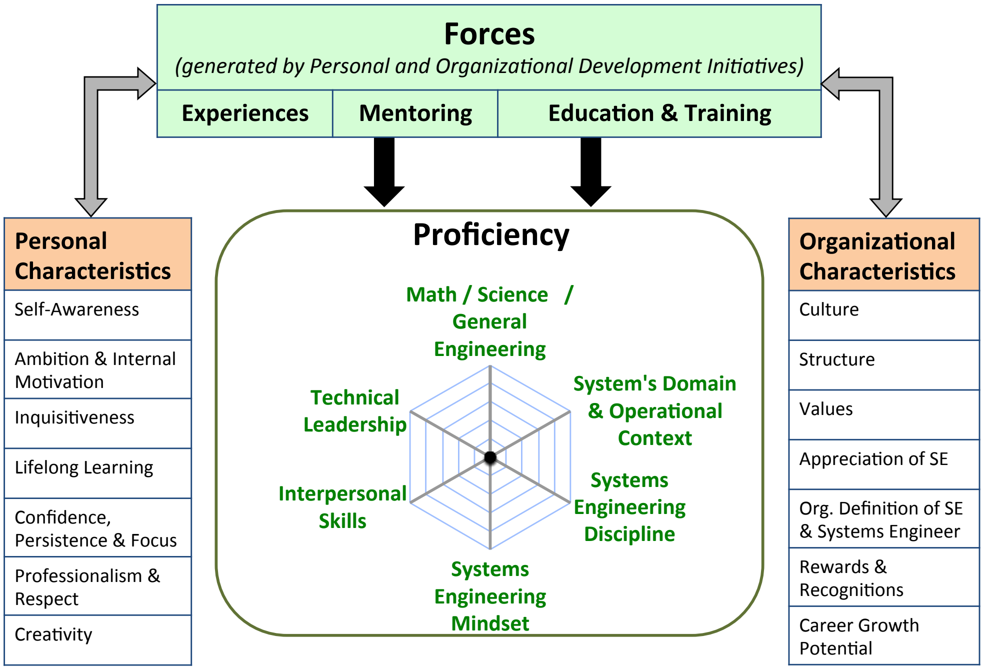

Figure 8. Forces, Proficiency and Characteristics

3.6.1 Personal Characteristics

Personal characteristics tend to be a differentiator between individual systems engineers. For example, two individuals with similar educational backgrounds and experiences undergoing the same training program may accrue different levels of benefits. Significant personal characteristics are identified below.

- Self-Awareness: The ability to self-reflect and become aware of one's own strengths, weaknesses, knowledge, and lack thereof.
- Ambition and Internal Motivation: The desire to reach high career positions, and the ability to draw motivation and energy from within in order to accomplish those high ambitions.
- Inquisitiveness: Possessing a high level of inherent curiosity, wanting to know more and have a 'hunger for knowledge'.
- Lifelong Learning: Always looking to learn and to keeping abreast with latest developments in related disciplines and systems, irrespective of seniority or position.
- Confidence, Persistence and Focus: Possessing the confidence to interact with stakeholders irrespective of their relative seniority or positions; the ability to stand firm and not give-up; and the ability to remain focused on the success of the overall system.
- Professionalism and Respect: Being professional in the conduct, mannerisms, and behaviors, and treating others with respect, recognizing that other experts may possess more knowledge and experience.
- Creativity: Combination of left-brain – right-brain, working together, bringing an artistic perspective to technical issues.

These personal characteristics influence how well a systems engineer may grow her proficiency based on the forces to which she is exposed. Likewise, personal characteristics also impact which forces an individual will seek out and whether an individual is likely to take advantage of organizational initiatives for her own growth and development. Some individuals also will generate their own independent initiatives, such as self-study, seeking training courses not offered by their organizations, or career path planning.

3.6.2 Organizational Characteristics

There are several characteristics of organizations that provide an indication of how difficult or easy it may be for a systems engineer to be effective. The primary characteristics are:

- Whether or how the organization defines "systems engineering" and "systems engineer".
- The organization's appreciation of systems engineering and perspective on the value that systems engineers provide.
- The organization's overarching culture, structures, and values.
- The organization's process for rewarding and recognizing systems engineering.
- The potential for career growth in the field of systems engineering.

The characteristics described above provide an overarching understanding of the organization and the importance it has placed – or not placed – on systems engineering. This will influence the types of initiatives an organization makes available to support the growth of the systems engineering workforce.

3.7 Dynamic Understanding from *Atlas*

The *Atlas* overview illustrated in Figure 5 can be considered as a quasi-static snapshot in time, but many of the elements of *Atlas* are dynamic in nature. The level of proficiency of an individual systems engineer is not fixed, but is constantly changing due to the impact of forces over time. Similarly, other elements of *Atlas*, including characteristics and initiatives of the individual systems engineer and of the organization, continue to change over time. Further, as the level of proficiency of an individual systems engineer increases over time, the organization is likely to place that systems engineer into different positions.

This dynamic aspect of *Atlas* is reflected in the career paths of individuals over time, as illustrated in Figure 9 below. *An individual's career path is the precise combination of the forces they undergo in the roles & positions she performs in over her entire career.* As described above, each of these forces has multiple characteristics and it is by layering those characteristics over time that one can begin to see their impacts over time.

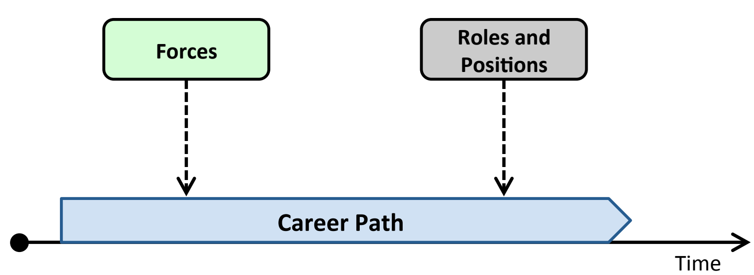

Figure 9. Career Path: A Dynamic View of *Atlas*

Figure 9 is a simplistic view of the interactions of the elements of *Atlas* over time, but as described above, each of these elements has its own characteristics that can be explored. For example, each position is a collective way to describe a set of related experiences. Layering the characteristics for the experiences associated with each position provides considerably more insight than a simple job title or even position description. Figure 10 offers an example of how these characteristics can be visualized.

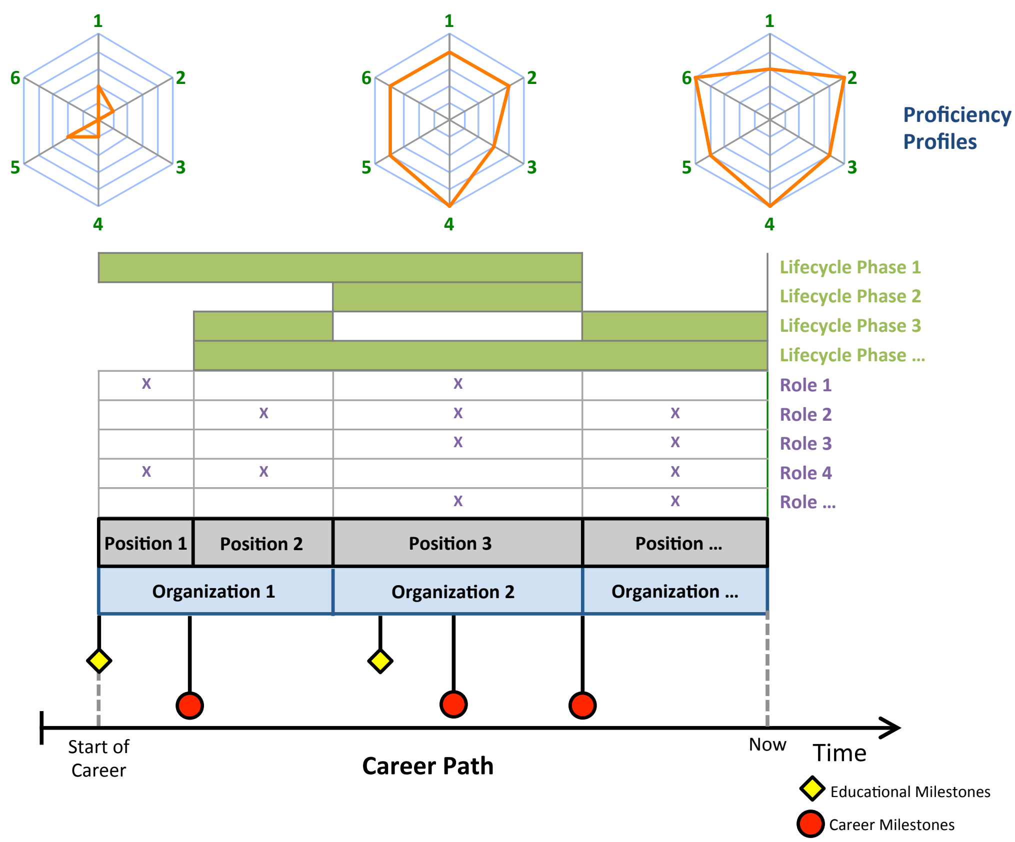

Figure 10. Visualizing a Career Path

This visualization pulls together the following elements of a career path:

- **Timeline:** Time is the dimension onto which all other elements of the career path are projected and visualized. The visualization helps understand the sequence, timing, and duration of various elements of the career path, offering valuable insights for developing the careers of systems engineers.
- **Educational Milestones:** The career of an individual typically begins when an undergraduate degree (or in some cases, a higher degree) is obtained. When, in which disciplines degrees are obtained, and how they impact other elements of the career path can be observed.
- **Career Milestones:** Significant milestones in terms of types of systems engineering positions, such as first leadership position, chief systems engineer, or program engineer, etc.
- **Organizations:** The variety of organizations and the time spent in each of those organizations can provide interesting insights, particularly if the organizations vary in terms of sectors, key domains, or other factors.

- **Positions:** The number and duration of all positions held across organizations are captured in the career path. How duration and educational qualifications affect positions can be observed.
- **Roles:** The roles performed in each of the above positions perhaps offer the most interesting insights into a career path. An individual is likely to perform more than one role in any particular position, but those roles typically vary as one's career progresses. Some roles performed earlier in one's career may no longer be performed, and there may newer roles that one plays later in her career. The types of roles performed concurrently offer insights into each position.
- **Lifecycle Phases:** The lifecycle phases experienced during each of the above positions are indicated along the career path. The duration and sequence of the lifecycle experiences indicates the exposure that an individual possesses. Similarly, some roles may be more relevant to particular lifecycle phases.
- **Proficiency Profiles:** The level of proficiency can be profiled at any point in the career with respect to the *Atlas* Proficiency areas. Possibly the most difficult to depict accurately across the career, the proficiency profile can be mapped onto the roles and positions that one performs. This visualization also helps to show, and how education and experiences influence proficiency.

The career path visualization currently does not include mentoring or training, but gathering all elements into a single visualization provides a holistic view of the entire career of an individual systems engineer. When multiple career paths of different individuals are visualized, patterns can be observed that can offer interesting insights for career development of future systems engineers.

4 VALUES THAT FOSTER EFFECTIVENESS

As defined in Helix, a systems engineer is effective when she consistently delivers value. This section explores the primary values provided by systems engineers across multiple industries as well as where they overlap with the values provided by project managers and classic engineers.

4.1 VALUES THAT SYSTEMS ENGINEERS PROVIDE

Individuals in the expanded sample were asked several questions to help validate the value provided by systems engineers. Systems engineers from outside the defense sector were asked the top value(s) that they personally provided as well as their perspective on the key value(s) provided by systems engineers overall. Project managers and classic engineers were asked, from their perspective, the key value(s) that the most effective systems engineers that they personally had worked with provided as well as their perspective on the value(s) that systems engineers *should* provide.

In particular, there is an appreciation for the big picture perspective systems engineers provide. This is particularly important for enabling successful integration activities, which were seen as another key value of systems engineers.

Systems engineers are also generally seen as effective at working with the customer; outside the defense sector, there is a generally stronger focus on customer experiences. Several interviewees who had previous experience in the government, but currently work in industry, explained that in a DoD environment, the Joint Capabilities Integration and Development System (JCIDS) process is often executed such that requirements are provided *to* systems engineers; often, they do not have an opportunity to participate in requirements development from the beginning of a project. Also, in the DoD environment, systems engineers are often separated from their external customers; so while a focus on the customer's needs *is* stated as important in the defense community, opportunities for direct interactions can be more limited.

In general, whether in the defense sector or other business sectors, systems engineers in government organizations tended to be more focused on providing value by emphasizing standard processes, while commercial organizations tended to focus more on delivering the "right" end results by asking good questions, generating a vision for the system, and providing the big picture perspective. This does *not* mean that systems engineers in government organizations value process over the end result of systems development; instead, it means that in an acquisition environment – which was the context for the majority of government systems engineers – following a rigorous process was seen as a primary way to provide value and help achieve end results. In commercial companies, process was discussed, but not seen as a key means for providing value, although systems engineers in commercial companies did state that systems engineers provide value by bringing a logical approach to problem solving. In some organizations, processes were seen as a way to institutionalize these types of approaches, although with varying degrees of success. It is worth noting that systems engineers in commercial organizations in highly regulated industries tended to emphasize process more strongly than their counterparts in less regulated commercial enterprises.

The values reported in *Atlas 0.5* are described in Section 3.2 above. The expanded data supports these findings. Any major differences seen in the expanded data set are described below. The values described in *Atlas 0.5* translated well outside of the defense community. This was the view not only of the systems engineers in the expanded dataset, but also of their peers.

There is a generally high respect for *effective* systems engineers across domains and organizations. Effective systems engineers, again, provide the values described in *Atlas*. However, program managers and classic engineers also stated that a problem with systems engineers, as a population, is that not all systems engineers *really* provide those values. When they do so, they are seen as critical to the success of programs, systems, and the organization. But in some organizations, their peers felt that up to a third of systems engineers are overly focused on rigid application of process, adding burden to programs rather than insight and value. This was consistent between government and industry organizations.

4.2 Values across Disciplines

Project managers and classic engineers were also asked what they felt were the top value(s) they provided through their own work, in addition to the insights in the values provided by systems engineers. Although these individuals in the expanded dataset were all mid-level or senior, they offered a few observations about more junior individuals in their disciplines:

- Classic engineers tend to provide value through the application of their education at a very detailed level. Electrical engineers may design a circuit or software engineers may write a section of code. It is their skills as individual contributors that are valued early in their careers.
- There are two main tracks for people in the classic disciplines based on their primary value:
    - Those highly valued as individual contributors will generally continue deeper into their disciplines, becoming subject matter experts within their particular domain.
    - Those who are successful as individual contributors, but also provide a broader perspective – for example, asking how changes might impact other parts of the system or trying to understand more clearly how customers intend to use a system – tend to become leaders within their particular domain.
    - Both the deep specialists and the broader experts were seen as critical to the successful development of systems, but their positions must be tailored to the types of values they more naturally provide. A mix of the two ends of the spectrum is critical for technological innovation and advancement.

Program/project management is not generally suited to junior-level individuals. At the mid- and senior levels, the most common themes heard were ways to help a program stay on track with planned budget and schedule. However, there were also overlaps with some of the values of systems engineers, although again often from a budget, cost, and resources point of view rather than a technical one:

- Enabling diverse teams to successfully develop systems.
    - Helping the team to understand the big picture perspective and where they fit within the larger picture.
- Managing emergence in both the project and the system
    - Projecting into the future, which includes staying "above the noise" of day-to-day development issues and identifying pitfalls.
    - Technical problem-solving balanced with the big picture perspective.
- Supporting the business cases for systems
    - Balancing traditional project management concerns of cost and schedule with technical requirements.

- Understanding the position of a system within the organization or customer's portfolio and communicating this to the team.

As described above, in the expanded dataset, there is clearly overlap between the values provided by program manager and leaders in classic engineering disciplines. Some of this overlap is complementary – for example when "projecting into the future", program managers tend to focus on things that might impact cost and schedule more than technical issues; systems engineers focus on technical impacts; together, there is a much better and more holistic understanding of the overall potential risks to a system.

5 POSITIONS AND ROLES

The systems engineering roles defined in *Atlas* 0.5 (Table 2 above) were validated by the systems engineers in the expanded sample. These roles were identified as common systems engineering activities by systems engineers and confirmed by their peers. The role of *Systems Engineering Evangelist* was mentioned, but outside of defense organizations, this seemed a very minor part of individuals' activities. Instead, individuals focused on how to provide direct value and therefore "prove the case for systems engineering" without focusing energies on this directly. For the role of *Logistics/Operations Engineer*, in commercial companies this role most often was focused on troubleshooting or updating design of a previously-released system.

Of the non-systems engineers included in the expanded dataset, nearly 100% reported having at least some activities that overlap those of systems engineers. Most classic engineers in the expanded dataset stated that they spent a portion of their time doing systems engineering activities, but often with a smaller scope. For example:

- They focus on end-user experience and interaction; but for a subsystem, focusing more specifically around their discipline.
- Leaders in the classic engineering disciplines often play a role in coordinating between subsystems, particularly in helping systems engineers understand the big picture to make informed technical decisions and understand system and subsystem trade-offs.
- They ensure quality both through design work and through verification and validation activities, though again, this is often for a subsystem(s) most relevant to their disciplines.
- As systems engineers lead multidisciplinary teams, senior classic engineers tend to lead engineering activities within their engineering disciplines.

The above insights all came from leaders in the classic engineering disciplines. Only about 7% of the individuals identified themselves as subject matter experts – so, an overlap with systems-related roles was more expected. Based on the commentary by these classic engineers, there is considerably less overlap for discipline SMEs, who tend to focus on technical depth and innovation. In addition, 100% of classic engineers had played the role of *Detailed Designer* at some point in their career.

Program managers likewise reported overlaps with systems engineering roles. The most obvious is that systems engineers sometimes take on *Program Management* responsibilities, and clearly this is the primary focus of a program manager. In addition, program managers reported commonly participating in *Customer Interface* activities. As with classic engineers, the scope is often different – focused on programmatic concerns over technical ones – but it is common for program managers to work with systems engineers in these interactions. Program managers may also be *Information Managers* and *Coordinators*. Again, their scope of influence is different than but often overlaps with those of systems engineers.

In some organizations, more particularly in government, there was tension reported when systems engineering roles overlapped with program management activities. A moderate overlap was tolerated or even seen as helpful, but if there was considerable overlap, program managers began to see the systems engineers as a "tax" on the program rather than as added value. Focus on scoping is a useful way to help ensure that any overlap is productive and not redundant.

6 PROFICIENCY

All of the individuals in the expanded dataset were exposed to the *Atlas 0.5* proficiency model (described in Section 3.3) in some way. Some were asked to simply respond to the model and its relevance while others were asked to actually assess themselves and their peers based on the model. All of the systems engineers in the expanded dataset agreed that the *Atlas* proficiency model was complete; no additional areas were recommended and although there were questions about specific skills, they were comfortable after discussion with the Helix team that these skills had a place in the existing framework. Project managers and classic engineers confirmed that the proficiency model covered the skillsets they believe are critical for systems engineers.

As with the findings in the original sample, although technical skills were seen as important, both systems engineers and their peers stated that the "softer" proficiencies – *SE Mindset*, *Interpersonal Skills*, and *Technical Leadership* – set effective systems engineers apart. One interesting difference between the expanded dataset and the original dataset was the emphasis on *System's Domain and Operational Context*. Particularly in government organizations, this is often seen as important, but less critical than other areas. Statements such as, "well, I have to know something about it, but if I have questions, I will just ask another engineer" were common. However, in the expanded set and particularly in commercial organizations, this was different: even for systems engineers, high proficiency in the domain was expected, to the point that systems engineers would often specialize in a particular type of technology because the learning curve to move between product lines was generally considered too steep.

The program/project managers and classic engineers in the sample also nearly unanimously agreed that the model was useful for themselves as well, though with some areas being less relevant than others:

- Most classic engineers stated that if their specific individual disciplines were added to the proficiency model, they could see it being a useful tool for themselves as well.
- *Math/Science/General Engineering* and *System's Domain and Operational Context* were consistently cited as critical to classic engineers. Because they tended to be responsible for more detailed design work than systems engineers would be at an analogous stage in their careers, this is not surprising.
- *Systems Engineering Discipline* was listed as important, but almost all non-systems engineers said this was not their real strength.
    - Classic engineers felt that, to the extent required, they pick these skills up on the job and typically had no formal training or education in this area.
    - Program managers felt that the *Lifecycle* and *SE Management* categories were particularly relevant for them, but the others were less critical.
- *Systems Engineering Mindset* was commonly seen as critical and appreciated.
    - This proficiency was consistently cited as critical to classic engineers who are going to be leading teams of engineers. Though many classic engineers cited "big picture perspective" as a value provided by systems engineers, they felt this was also important for leaders in any engineering discipline.
    - Overall, this was seen as less critical for the deep specialists and individual contributors (the SMEs).

- Project managers also cited this as a critical proficiency, although they explained that their value in exercising this proficiency comes from the balance they can provide to systems engineers and vice versa: project managers offer insight into the business or even political "big picture", while systems engineers provide the technical "big picture"; the two together then provide the best opportunities for making good decisions on projects.

- *Interpersonal Skills* and *Technical Leadership* were cited as important throughout the expanded dataset.
  - The classic engineers in the expanded dataset not only emphasized that these proficiencies were important to lead a team of engineers, but those who performed self-assessments generally rated themselves well in these areas and also demonstrated these skills in their interviews. Ironically, these areas are commonly cited as a weakness for classic engineers – and the interviewees generally agreed. These skills were seen as an indicator of someone who was likely to become a leader in an engineering discipline. For individual contributors and SMEs, these skills were seen as important but less critical than hard *Math/Science/General Engineering* skills.
  - The program/project managers indicated that of all the proficiency areas, these were probably the most critical for their positions and the best aligned with their responsibilities. Subsequently, they often emphasized these areas and those completing self-assessments reported these areas as their strongest.
  - Interviewees from non-defense organizations commonly stated their organizations offered a high variety of quality training opportunities in these areas.

- Within *Technical Leadership*, the *Business Acumen* category was sometimes cited as important in defense organizations – but process focused, interpersonal aspects, etc. were much more consistently cited as critical in the defense industry. Many systems engineers in government defense organizations felt that while understanding business cases would be a "nice to have", the current acquisition model precludes them from having to understand the "business" case. Business Acumen was consistently discussed as more critical outside of defense organizations. This seems reasonable because commercial organizations must be responsive to market pressures and opportunities. They are "provided requirements" less often, unlike their defense systems engineer counterparts.

7 INSIGHTS ON THE FORCES THAT IMPACT PROFICIENCY

In general, the findings elaborated in (Pyster et al. 2015) around the forces held true for systems engineers outside the defense sector as well as for their peers both within and outside the defense sector. For example, 100% of the expanded sample still agreed that experiences were the most critical force for development and that mentoring and education and training were the other most critical forces.

This section highlights areas where, based on either their position or organization, there were key differences seen in interviewees' views regarding the forces.

7.1 EXPERIENCES

Atlas 0.5 provides a detailed discussion of the various characteristics of experiences and how they map to systems engineers' growth. Overall, the patterns in the expanded data set match the patterns seen in the original dataset. For example, for all systems engineers there was an emphasis on the need for breadth of experiences in terms of roles played, parts of the lifecycle experienced, exposure to different domains, etc. There were a few minor differences:

- In general, organizations outside the defense sector worked on systems with much shorter lifecycles. This provided greater opportunities for the development of systems engineers. For example, a common recommendation in the defense sector was for an individual to follow a single system throughout the full lifecycle to help her really understand how decisions made early impact the system later on. However, when a system's lifecycle is scheduled for 15 years and there are current and anticipated gaps in the workforce that necessitate more rapid growth of systems engineers, it is not practical to have a single individual attached to a single system for this length of time. Commercial organizations working on systems with much shorter lifecycles were generally better able to help its systems engineers foster a full lifecycle perspective early in their careers.
- Perhaps not surprisingly, although breadth was emphasized for systems engineers, depth was much more heavily emphasized for classic engineers. There was a sense that even the leaders of teams for the classic engineering disciplines needed to have several very deep engineering experiences in order to be credible and to understand sufficiently the work required of their teams.
- Rotational programs – a fairly common way to provide systems engineers exposure to multiple systems, roles, and phases of the lifecycle – were less frequent for non-systems engineers. Most rotational programs were focused on individuals early in their careers. Given the focus on depth over breadth, particularly early on for classic engineers, this is not surprising.

Classic engineers and systems engineers almost always were *Detailed Designer*s very early in their careers. While systems engineers typically moved away from these types of responsibilities within a few positions, classic engineers continued to play these roles and gained more depth.

7.1.1 EXPERIENCES INSIGHTS ON INCOSE DATA – CHIEF SYSTEMS ENGINEER EQUIVALENTS

Helix research recognizes the Chief Systems Engineer (CSE) position as a top technical position. The INCOSE Systems Engineering Professional (SEP) certification program applications dataset contains information on individuals who have been certified as Expert Systems Engineering Professionals by

INCOSE, and includes organizations from both inside and outside the defense sector and from different countries. The applicants described positions that were equivalent to CSE but may have had a different title, such as Chief Architect or Chief Engineer. From the INCOSE SEP data, Helix identified 61 individuals who held at least one CSE or equivalent position, herein referred to as "ChiefX."

A full 61% of the ChiefXs held just one ChiefX position at the time they applied to become and ESEP; 23% reported two ChiefX positions; and only 16% of the subset reported three or more ChiefX positions. To begin to understand characteristics of the career path for these individuals, Helix analyzed the first ChiefX position reported.

Based on descriptions in ESEP applications for the first ChiefX position, Helix binned the ChiefXs into one of four categories: *Defense Industry* (for people who work on systems for the armed forces); *Commercial Industry* (for people who work on purely commercial systems); *Defense and Commercial Industry* (for people who worked on both defense and commercial systems); and *DoD* (for people employed by the Department of Defense). Although it is certainly possible for someone's first ChiefX position to be for a civilian government agency, there were none in the sample set of 61 ChiefXs.

As shown in Table 3, the 65% of the sample population worked in the defense industry in their first ChiefX position. Because so many of INCOSE's members are from the defense community, this is unsurprising.

Table 3. Areas and Sectors of Systems in First ChiefX Position

Sectors	Defense Industry	Commercial Industry	Defense and Commercial Industries	DoD	Total
Aerospace	15%	2%	3%	2%	21%
Intel	13%			3%	16%
Communications	10%			2%	11%
Aeronautical	10%				10%
IT	3%	3%			7%
Software		5%	2%		7%
Missiles	3%			2%	5%
Other		2%	3%		5%
Satellite	3%				3%
Combat Ship	2%				2%
Combat Vehicle	2%				2%
Controls	2%				2%
Energy		2%			2%
Marine		2%			2%
Nuclear				2%	2%
Security	2%				2%
Surveillance			2%		2%
Transportation		2%			2%

To further understand the demographics of the sample, the team further categorized each ChiefX by the type of systems on which she worked in her first ChiefX position. Of the 18 identified sectors, people in just four of them (aerospace, intelligence, communications, and aeronautics) account for 58% of the population. There is no available data to explain why so many of the ChiefXs work on these four types of systems.

Within position descriptions, the applicants also described (to varying levels of detail) the work performed on each system. Based on these descriptions, similar to the roles analysis performed for the Helix interviewees, a roles analysis was performed on the first ChiefX position and is displayed in Figure 11. In general, the roles performed across the subset are very similar, but there are some noteworthy differences: all individuals from *DoD* and *Commercial Industry* perform the *Requirements Owner* role, and all individuals from *DoD* perform the *Validation and Verification* role. In contrast, none of the *DoD* ChiefXs perform management-type roles, *Program Manager* and *Organizational Manager*. This may indicate that these individuals take on more hard technical systems engineering responsibilities. Those ChiefXs who worked on both defense and commercial systems were less likely than their counterparts to take on the *Customer Interface* role, and similar to the *DoD* classification, never took on the *Program Manager and Organizational-Functional Manager* role.

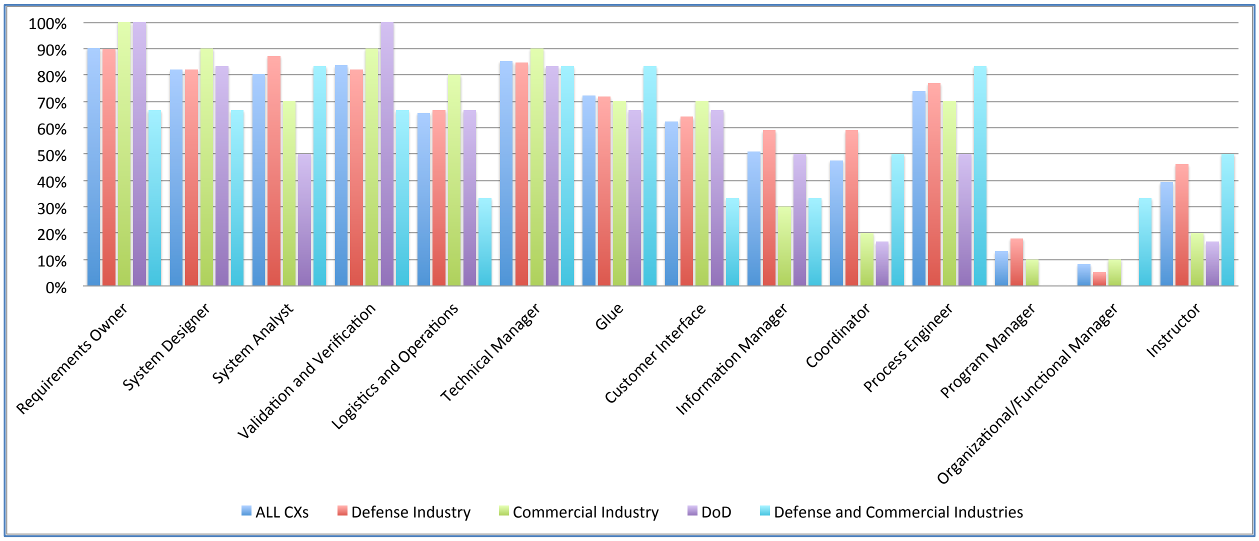

Figure 11. Roles Played in the First ChiefX Position

More than 80% of the ChiefXs in the defense industry played the roles of *Requirements Owner*, *System Analyst*, *Verification and Validation*, and *Technical Manager.* For those in commercial industry, more than 80% of the ChiefXs played the roles of *Requirements Owner*, *System Designer*, *Verification and Validation*, and *Technical Manager*. The standout difference between the two groups is that defense ChiefXs are very likely to do systems analysis, while commercial ChiefXs are quite likely to do system design. This distinction may reflect the fact that commercial systems tend to have greater degrees of freedom than do defense systems.

7.2 MENTORING

Atlas 0.5 elaborates further on the differences between formal and informal mentoring; and on the benefits to the mentor, mentee, and to the organization. Whenever the topic of mentoring was discussed during Helix interviews with systems engineers outside of the defense sector or with classic engineers, the interviewees expressed similar thoughts and perspectives, as already captured in *Atlas 0.5*. The following observations made by Helix might explain the fact that there were no aspects of mentoring that stood out as differentiators:

- When a formal mentoring initiative is established by an organization, it is usually for the benefit of the organization at-large, and not limited to systems engineers or the systems engineering division (or equivalent).

- Whenever informal mentoring arrangements are established, it is reflective of the organizational culture, which again, is not limited to the systems engineers. It was common for systems engineers to have non-systems engineers as their mentors, especially for career or organizational mentoring.

7.3 Education and Training

As with the original dataset, education and training were reported as important for the development of systems engineers in the expanded dataset as well as important for classic engineers and program managers. There were a few overarching observations regarding education and training from the expanded dataset:

- Systems engineering training is generally more formalized in the defense community. Most of the defense organizations in the original dataset had multiple systems engineering training opportunities, many ranging from days to weeks and covering a wide variety of systems engineering specific topics. In the commercial organizations, this was much less common; "lunch-and-learns" and one-hour seminars were much more typical. Overall, commercial organizations took the perspective that most SE learning should occur through on-the-job training.
- Systems engineers outside the defense sector are highly educated, with a higher percentage of individuals in the expanded sample having master's degrees and PhDs than in the original sample. However, systems engineering master's degrees were common in the original sample and much less common in the expanded sample. In commercial companies there was generally a lack of awareness about systems engineering degree programs, and their subject matter, availability, and benefits.
- Technically related training seems less prominent in commercial companies than in defense organizations. A common refrain was that individuals were expected to come into these organizations with exceptional technical skills, so there was less need for this type of training. Some commercial organizations have such high expectations for technical skills, even for new hires, that training is focused almost exclusively on soft skills. Commercial organizations in the expanded dataset did offer training opportunities, but these had a much heavier focus on soft skills: communication, teamwork, leadership, etc. It was common for the program/project managers in the expanded sample to have taken many of these offerings.

7.3.1 Education Insights on the Expanded Helix Dataset

The Helix team compared the educational backgrounds of the individuals in the original and expanded datasets. Table 4 shows the differences in the highest degree attained between the original and expanded dataset. The education levels of the two datasets are fairly similar, and in the original dataset, education levels were fairly consistent across organizations. However, it varied quite a bit between organizations in the expanded dataset. For example, for one organization in the expanded dataset, the rate of doctoral degree attainment was actually 29%.

Table 4. Highest Degree Attained by Individuals

	Original Dataset	Expanded Dataset
Associate's	0%	0%
Bachelor's	33%	42%
Master's	58%	51%
Doctorate	9%	7%

Bachelor's degree majors in the original dataset were quite dispersed; in the expanded dataset they are more closely clustered around a small number of majors, with 95% in engineering disciplines as shown in Figure 12. The major of biomedical engineering did not occur at all in the original dataset, but appeared with individuals in the healthcare industry. Mathematics degrees are also much more common in the expanded dataset than in the original.

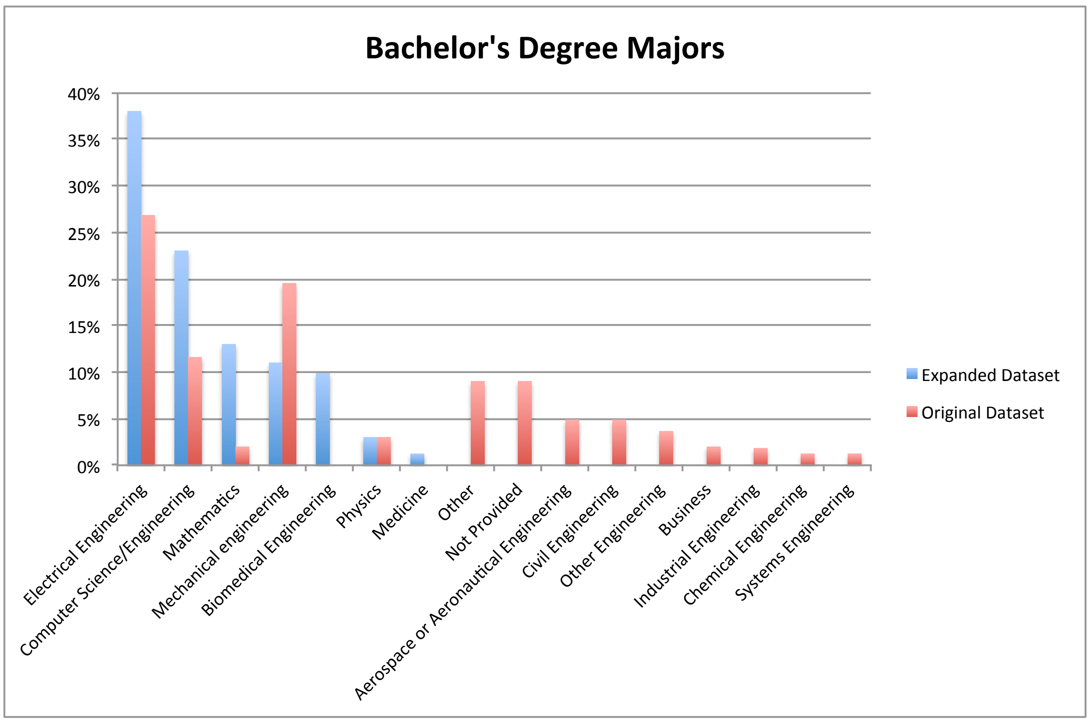

Figure 12. Comparison of Bachelor's Degree Majors for The Original and Expanded Datasets

For the areas of graduate study, the expanded dataset actually showed more variability than did the expanded dataset. As shown in Figure 13, the mathematics and natural sciences fields were more common in the expanded dataset, as is biomedical engineering. Management degrees were more common outside of the defense industry, while systems engineering was less common. As mentioned above, it was common for individuals outside the defense sector to not even be aware that systems engineering master's programs existed. It is not surprising that the classic engineering disciplines have more master's degree representation in the expanded sample than the original sample because the expanded sample includes classic engineers.

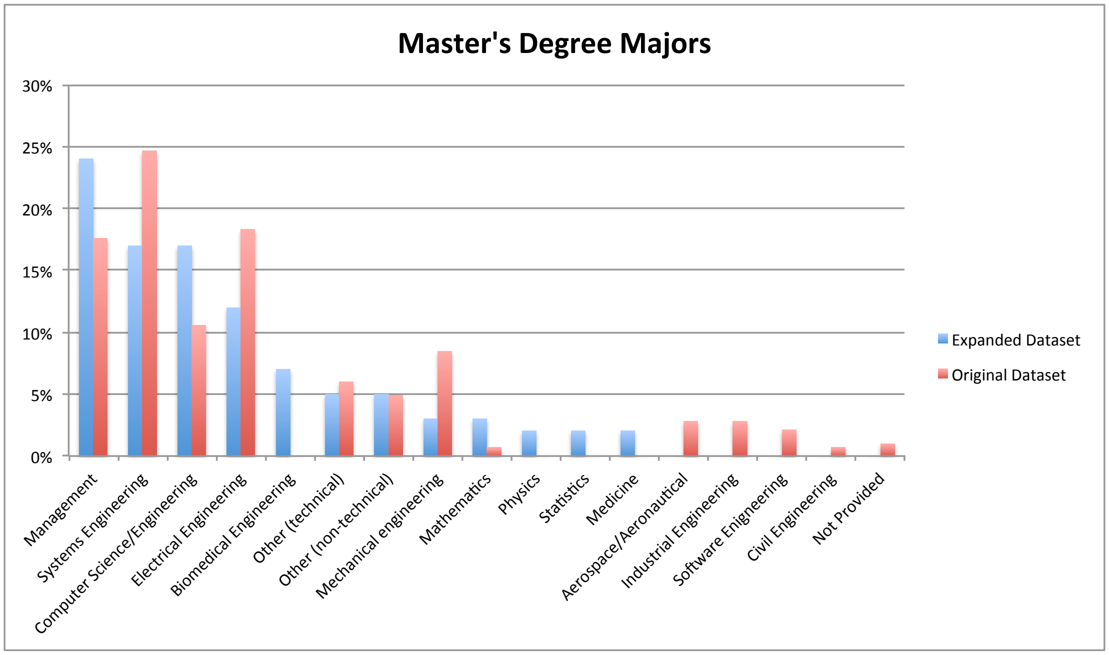

Figure 13. Comparison of Master's Degree Majors for The Original and Expanded Datasets

For doctoral education, 33% of the doctoral degrees in the original dataset were in systems engineering and the other degrees were one-offs. In the expanded dataset, none of the doctoral degrees were in systems engineering. Instead, a third were in biomedical engineering (33%) and nearly a quarter (22%) in physics.

7.3.2 Education Insights on INCOSE Data – Chief Systems Engineer Equivalents

The ChiefX sample represents several domains, and this is reflected in their education. Consistently, for all populations studied by Helix, systems engineers are a very educated group. As shown in Table 5 at least 50% of each classification attained at least one graduate degree. Six individuals, four from the *Defense Industry*, one from the *Commercial Industr*y, and one from *Defense and Commercial Industry* classifications, have 2 bachelor's degrees; and one person, also from the *Defense and Commercial Industry* classification has 3 bachelor's degrees. There were twelve individuals in the subset with 2 master's degrees: two from *DoD,* two from *Commercial Industry*, two from *Defense and Commercial Industries* and six from *Defense Industry*.

Table 5. ChiefX Highest Degree Attained

Highest Degree Attained	Defense Industry	Commercial Industry	DoD	Defense and Commercial Industries
Bachelor's Highest	23%	30%	17%	0%
Master's Highest	62%	50%	50%	83%
PhD Highest	15%	20%	33%	17%

Systems engineers most frequently have a bachelor's degree in Electrical Engineering. Table 6 shows the breakdown of bachelor's degree majors attained for each classification. Unsurprisingly, the most popular majors are Electrical Engineering (or a similar major), Mathematics, Chemistry, Engineering/Engineering Science and Mechanical Engineering. All ChiefXs have at least one bachelor's degree, and since some people attained more than one bachelor's degree, the percentages do not equal to 100% for each classification.

Table 6. ChiefX Bachelor's Degree Majors

Bachelor's Degree Majors	Defense Industry	Commercial Industry	DoD	Defense and Commercial Industries
Electrical Engineering (and Electronics, Electronical Technology)	41%	60%	33%	33%
Chemistry		10%		50%
Engineering / Engineering Science	5%	10%	33%	
Mechanical Engineering	8%		17%	17%
Business Administration / Administration Science / Business	3%			33%
Aerospace Engineering / Astronautical Engineering	10%			17%
Mathematics	10%	10%		
Aeronautical Engineering / Aviation	3%		17%	
Computer Engineering / Computer Science /Computer and Information Sciences	15%			
Philosophy		10%		
Accounting	5%			
Computer Science/Mathematics	3%			
Music Education	3%			
Physics with Electronics emphasis	3%			
Quantitative Decisionmaking	3%			

The most common master's degree major attained by systems engineers is Electrical Engineering. The second most common master's degree pursued is related to management, as seen in Table 7. Figures in this chart are based on percentages of the number of people in each classification, and since some individuals do not have a master's degree, and some have 2 master's degrees, the percentages do not equal 100% for each classification. However, patterns can be observed for trends in majors, besides management. A Systems Engineering master's degree is common for all classifications, surprisingly except for the *DoD* classification. This is a very small subset (6 individuals) and perhaps is not representative of the larger population. The other majors pursued are representative of classic engineering disciplines or are branches of classic engineering disciplines.

Eleven individuals attained doctoral degrees. The top three PhD degrees attained were in: Computer Engineering/Computer Science, Engineering/Engineering Science and Systems Engineering. Others achieved a doctoral degree in Applied Mechanics, Electrical Engineering, Mechanical Engineering and Law.

Table 7. ChiefX Master's Degree Majors

Master's Degree Majors	Defense Industry	Commercial Industry	DoD	Defense and Commercial Industries
Electrical Engineering (and Electronics, Electronical Technology)	15%	10%	33%	33%
Engineering Management / Systems Management / Technology	18%	20%		33%
Systems Engineering / Systems Technology / Systems Integration	15%	10%		17%
Business Administration / Administration Science / Business Management / Management	8%	10%	17%	
Mechanical Engineering		10%		17%
Engineering / Engineering Science	5%		17%	
Aeronautical Engineering / Aviation			17%	
Aerospace Engineering / Astronautical Engineering				17%
Mechanical and Aerospace Engineering			17%	
Nuclear Engineering			17%	
Computer Engineering / Computer Science /Computer and Information Sciences	15%			
Computer Science/Mathematics		10%		
Psychology		10%		
Thermodynamics		10%		
Operations Research / System Analysis (OR/SA) Strategic & Tactical Science	5%			
Applied Mechanics	3%			
Control Systems	3%			
Electrical and Computer Engineering	3%			

8 PERSONAL CHARACTERISTICS AND INITIATIVES

In general, individuals in the expanded data set were less aware of systems engineering resources outside of their organization than were individuals in the original dataset. For example, when asked how they dealt with questions on process or issues they had not seen before, many systems engineers in the expanded dataset indicated that they would coordinate with their peers within their organizational unit; if that failed, then with others outside their organizational unit but still within their business unit; and finally, if that failed, then with people outside their business unit. When asked when they would ask for help outside of their organization, most systems engineers indicated they never had. Systems engineers in the organizations interviewed tended to focus on their branded or proprietary approaches; in some instances, they even indicated that discussing techniques with systems engineers outside of their organization would be seen as "disloyal". However, additional probing indicated that this could not account for all of the differences seen between the expanded and original datasets.

Overall, outside of the defense organizations, there seemed to be a much lower level of awareness of the wider systems engineering community. There was much less awareness of systems engineering as a distinct professional discipline in commercial companies than the Helix team expected. For example, when asked whether they were familiar with INCOSE, all but a few systems engineers in the expanded sample said they had never heard of the organization.

When asked how commonly individuals would seek a master's degree in systems engineering, many individuals in the expanded dataset indicated that they did not know that graduate programs for systems engineering existed at all, let alone did they know anyone who had such a degree. Similarly, there was almost no awareness of certification options for systems engineers or community resources such as the *Guide to the Systems Engineering Body of Knowledge (SEBoK)* or any of the handbooks on systems engineering from such organizations as INCOSE and NASA.

One of the recommendations from the *Atlas 0.5* report centered on career paths – that individual systems engineers have a responsibility to shepherd their own career paths. This was complicated by the fact that most participating organizations do not have clear career paths for systems engineers. These observations also held true for systems engineers in the expanded dataset. Overall, classic engineers and project/program managers had much more clearly defined expectations for their career paths and received more guidance from their organizations.

9 ORGANIZATIONAL CHARACTERISTICS AND INITIATIVES

Individuals in the expanded dataset agreed that the organizational characteristics included in *Atlas* are relevant and impact the effectiveness not just of systems engineers, but often of program managers and classic engineers as well. There were some insights based on the characteristics of the organizations that participated in the expansion, as discussed below.

Overall, defense organizations tended to show more maturity in how systems engineering was defined and systems engineers were identified than did commercial organizations. This does not mean that the defense organizations were without problems, but that they had historically made an effort to formalize these things more strongly. Though these efforts did not eliminate all confusion about what systems engineering is and who systems engineers are, they were more advanced in these areas than their commercial counterparts. This is not surprising given the emphases on systems engineering in the defense community for several decades, but the lack of maturity around the definition and identification of systems engineers in commercial companies is an inhibitor to their effectiveness. In discussions with program managers and classic engineers, they commonly cited that they had trouble understanding “who is really a systems engineer”. Systems engineering activities were common, but the identifying vocabulary to discuss them consistently less so. Even when an organization did define systems engineers or systems engineering, the terms were often inconsistently applied. While this happened within the defense community as well, the inconsistencies were more pronounced in the commercial sector.

Likewise, there were notable differences in systems engineering terminology between defense and commercial organizations. For example, many systems engineers and non-systems engineers outside the defense sector questioned the use of the term “ConOps” in the proficiency model; when this was expanded to concept of operations, they understood it, although it was still an unfamiliar term to many. The terminology used to describe lifecycles varied greatly between defense and commercial organizations. Another example is that the term “requirements” is not as commonly used outside the defense community; instead commercial organizations focus on “market needs”, “gaps in competitor capabilities”, or “opportunities”. Even between units of the same parent organization, in non-defense organizations, there was more inconsistency in how systems engineering terms were used.

Non-defense organizations were more mature in applying aspects of systems engineering beyond their technical staff. For example, in several organizations, there was training for executives and managers on systems thinking or the systems approach. There were even efforts to apply systems engineering principles to the organizations themselves – to systematically and logically approach the melding of organization, process, and policy. There were multiple examples of these enterprise systems engineering efforts in non-defense organizations.

10 Overarching Findings

10.1 Findings

Analysis of the expanded dataset supports the idea that *Atlas* is applicable beyond the defense sector and to classic engineers and program/project managers. Individuals in related disciplines felt that many aspects of *Atlas* were applicable to themselves, or would be applicable with some tailoring.

- **Effectiveness.** The definition of effectiveness found in *Atlas – An individual systems engineer is effective when she consistently delivers value* – is applicable to systems engineers across domains. It is equally applicable to people from other disciplines if the term "systems engineer" is replaced by a term reflecting their disciplines.
- **Value.** The values described for systems engineers in *Atlas* are applicable and consistent outside the defense industry. The program managers and classic engineers also confirmed that these values were the critical value-adds for systems engineers.
- **Proficiency.** The proficiency model of *Atlas* applies well to systems engineers outside of the defense sector. For individuals in other disciplines, many of the proficiencies are relevant, although the proficiency model would have to be tailored to be fully applicable; e.g., to include a discipline-specific proficiency area, such as one on Electrical Engineering for people who are electrical engineers. *Math, Science, and General Engineering* skills are more highly valued by classic engineers throughout their careers; *Technical Leadership* skills are very important to project managers. For *senior* classic engineers, *Technical Leadership*, *Interpersonal Skills,* and *SE Mindset* are critically important.
- **Lifecycle.** In general, organizations outside of the defense sector worked on systems with shorter lifecycles than seen in the defense sector. Shorter lifecycles can provide more opportunities for systems engineers to see the full systems lifecycle – identified in *Atlas* as important for the maturation of systems engineers. However, some of the organizational issues that can lead to individuals being pigeonholed in a certain aspect of systems do still exist outside of the defense sector.
- **Personal Characteristics.** The personal characteristics of systems engineers identified in *Atlas* were equally applicable outside of the defense sector. These personal characteristics were also seen as critical to the maturation of senior individuals in other disciplines. One of these characteristics – lifelong learning – was highlighted as critical during all phases of an individual's career, whether for systems engineer, project management, or classic engineering, and across all types of systems identified.

10.2 Recommendations:

The *Atlas* recommendations provided in (Pyster et al. 2015) are applicable to the systems engineers in the expanded dataset. There are also a few additional recommendations:

- Organizations outside the defense community need should raise awareness among its systems engineers of resources in the broad systems engineering community; e.g., of the Systems Engineering Body of Knowledge.
- Organizations outside the defense community should raise awareness among its systems engineers of graduate systems engineering programs. Currently, there is little awareness of

these programs. Organizations should make a more deliberate calculation as to whether they want their workforce to earn these degrees.

- Systems engineers working outside of the defense community should acquaint themselves with the professional societies related to systems engineering such as INCOSE or the IEEE Systems Council.

11 FUTURE DIRECTIONS

Helix will continue the work begun here to expand beyond the defense sector and to explore the applicability of *Atlas* beyond systems engineers. In the past, the Helix team has done relatively small-scale efforts – generally 12 to 30 individuals – with many organizations. In 2016, the Helix team will work much more closely with a small number of organizations to pilot the implementation of *Atlas* and develop a deeper understanding of the systems engineering workforce in each organization. This will provide opportunities to further validate and refine *Atlas*, leading to *Atlas 1.0* by the end of 2016.

The major 2016 directions for Helix, therefore, are:

- **Validating *Atlas***: Being developed using a grounded theory-based approach, *Atlas* is reflective of the data that has informed the building of the theory. Validity of the elements of *Atlas*, particularly of the proficiency model, and the career paths of systems engineers outside the population of the current Helix interviewees is to be established. To support this, validation will be an explicit objective of upcoming Helix site visits.
- **Expanding the Industry Sectors and System Types**: In addition to validation, continuing to expand Helix beyond the defense sector is expected to provide new insights and refinements for *Atlas*. Helix will continue to reach out to commercial organizations from different sectors, and organizations developing different types of systems – in scale, complexity, and domain.
- **Strengthening the Dynamic View of *Atlas***: Career paths of systems engineers capture the dynamic aspect of *Atlas*. This will be further explored in 2016 to better understand how proficiencies change over time and to be able to more accurately predict future changes in proficiency levels as a result of specific forces. Appropriate modeling tools and simulation techniques will be explored.
- **Supporting Independent Atlas Deployment:** *Atlas 1.0* will not only present a more mature version of the theory of effective systems engineers, it will also provide several of the artifacts needed by individuals and organizations to independently use *Atlas* for personal and workforce development.
- **Engaging on a Large-Scale:** Until now, organizational participation in Helix has been on a small to medium scale in terms of the systems engineers who participated in Helix interviews, compared to the entire systems engineering population within an organization. If presented with the opportunity, Helix anticipates engaging an organization on a large-scale, interacting with both systems engineers and those who work with them. Such an engagement will provide substantial new opportunities to further validate and refine Helix.
- **Community Building:** Helix workshops will continue to be a forum for various Helix stakeholders to review the progress and plans of Helix; for organizations who have already participated in Helix to share the experiences; for other organizations to share their expectations; and for the systems engineering community at large to set the expectations for Helix that would be most valuable. Additional mechanisms beyond workshops will be sought to grow the Helix community.

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GLOSSARY

ACRONYMS AND ABBREVIATIONS

Acronym	Definition
CSE	Chief Systems Engineer
DIB	Defense Industrial Base (that supports DoD)
DoD	U.S. Department of Defense
INCOSE	International Council on Systems Engineering
IT	Information Technology
MBA	Master of Business Administration
NASA	National Air and Space Association
NDIA-SED	National Defense Industrial Association – Systems Engineering Division
SE	Systems Engineering
SERC	Systems Engineering Research Center
SEBoK	*Guide to the Systems Engineering Body of Knowledge*
SME	Subject Matter Expert
UARC	University-Affiliated Research Center
PM	Project (or Program) Manager

TERMS

career path – the precise combination (in terms of characteristics, timing, and order) of experiences, mentoring, and education and training that they undergo during their entire career.

chief systems engineer (CSE) – one who has formal responsibility to oversee and shepherd the technical correctness and to maintain a consistent vision for a system, often coordinating with many other systems engineers who have smaller scopes of responsibility.

effective systems engineer – someone who consistently delivers value by performing systems engineering activities in positions assigned by the organization.

position – equivalent to a 'title', a position is held by an individual; the organization defines what roles and responsibilities it entails.

proficiency – the quality or state of knowledge, skills, abilities, behaviors, and cognition of an individual.

role – a specific set of related activities; the roles identified in *Atlas* are specific to systems engineers..

systems enginee*r* – an individual who performs systems engineering activities and is recognized (either formally or informally) by his or her organization for her ability to perform these activities.