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IMPLEMENTING A SYSTEMS ENGINEERING CULTURE WITHIN FEDERAL AGENCIES

by

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This paper examines the potential value of implementing a systems engineering culture within federal agencies to maximize returns on limited resources and provides recommendations for implementing a systems engineering culture within constraints of the agency environment. Prior to executing a culture change initiative, agencies must conduct planning and analysis activities to objectively determine whether a systems engineering culture is likely to bring expected return on investment. Existing case studies and research literature on systems engineering and public organizational culture were analyzed to create a comprehensive approach for the federal setting. Analysis shows that systems engineering application can provide significant return on investment for agencies with high levels of program and project complexity, if it is appropriately resourced and supported by a systems engineering–oriented culture. Due to the unique constraints of the public arena, implementing a systems engineering culture within federal agencies requires following a culture change implementation framework specifically formulated for the federal agency environment. Agency leadership engagement and active participation play a key role in successful culture change.

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IMPLEMENTING A SYSTEMS ENGINEERING CULTURE WITHIN FEDERAL AGENCIES

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TABLE OF CONTENTS

LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS AND ABBREVIATIONS

DoD	Department of Defense
GAO	Government Accountability Office
GS	general schedule
HR	human resources
IEEE	Institute of Electrical and Electronics Engineers
INCOSE	International Council on Systems Engineering
IT	information technology
NASA	National Aeronautics and Space Administration
NDIA	National Defense Industrial Association
OPM	Office of Personnel Management
PC	project challenge
ROI	return on investment
SE	systems engineering
SEC	systems engineering capability
SECCM	Systems Engineering Career Competency Model
TOC	total ownership cost
WGI	wage grade increase
U.S.	United States

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EXECUTIVE SUMMARY

Implementing a systems engineering (SE) culture within federal agencies may enable certain types of applicable agencies to gain significant performance efficiencies. In a time of substantial performance constraints, including budget cuts, workforce reduction measures and ineffective workforce management tools, agency mission continues to expand. Federal agencies are required to increase performance efficiencies to make the most of limited resources in order to meet swelling demand. Applying SE methods within agencies whose mission aligns well with SE concepts offers a possible means to increasing performance efficiencies because SE is rooted in holistic planning, analysis, risk mitigation, and managing complexity. However, a supportive SE-oriented culture must be present within the organization for such efficiencies to be achieved.

Aligning organizational culture with the organization's goals and strategies is a well-documented means to increase performance efficiency but requires calculated investment into a culture change initiative. Culture initiatives can be costly and are subject to high degree of failures (Bustin 2014). To be successful, heavy employment engagement and buy-in across the organization is required. The probability of success can be increased by following a culture change framework (Heathfield 2017). Most culture change frameworks are oriented towards private industry and do not address the unique environmental factors and constraints which face public agencies such as the federal government. These frameworks must be adapted to address public organizational factors and constraints in order to be effective. Those organizations which choose to move forward with an SE culture must be prepared to undergo a culture change initiative to move from their current culture to the desired cultural state.

As a public organization, federal organizational culture is affected by many unique environmental factors and constraints, including its bureaucratic structure, high degree of visibility, changing political agendas, human resource practices and budget constraints (Drumm 2012). Though culture will vary by individual agency, these common factors and constraints greatly shape the existing federal culture by strictly limiting the usage of extrinsic motivational tools. Extrinsic motivators include tangible items such as salary and

bonuses; environmental factors and constraints preclude the federal government from using these tools as significantly and effectively as private industry. Consequently, the federal government will need to adapt to its constraints and emphasize the cultivation of intrinsic motivation. The theory of public service motivation supports the premise that those employees self-selecting into the public service arena are service-minded individuals (Perry 2000, 484). Intrinsic motivation such as desire to serve the mission and community, job satisfaction and pride in one's work can be cultivated as part of the culture change initiative to attain employee buy-in to the change.

Optimizing culture requires the agency to consider the type of culture which best supports their requirements and take internal steps to curate that orientation type to the appropriate level of maturity. Where the agency goal is to increase efficiency, mitigate risk, and optimize resourcing, implementing an SE-based culture should be a primary consideration. An SE culture is defined by the International Council on Systems Engineering (INCOSE) as "an umbrella of shared values and behaviors that transcends the individual cultures of teams, departments, and disciplines—rooted in the appreciation of overarching system concepts and system relationships" (Carroll 2016, 4). It has several attributes, including fostering cross-organizational communication channels, empowering decision making, emphasizing critical thinking and a systems-based perspective and a receptive leadership body.

Prior to making the commitment to undergo an SE culture change, it is recommended that the organization conduct careful analysis of the expected return on investment (ROI) for the initiative. The determination that an SE culture is an optimal fit for the agency requires careful analysis to justify resource investment. Accurate value assessment requires that the agency understand the key functions, processes and attributes of SE itself and the overall organizational value which may be derived through application of SE activities and support functions. Case study and literature review support conventional SE heuristics and present consistent quantitative findings regarding the value of applying SE to product and system development projects (Elm 2013). Value was optimized in a variety of ways, including budgetary savings, lower total ownership cost (TOC), schedule gains and operational gains. Based on the results of conducted

quantitative analysis, SE appears to offer the most benefit to organizations which often have projects with high levels of complexity. To fully benefit, the organization must integrate a supportive SE culture which fosters SE to necessary levels. However, that is not to say that all projects must be technically or engineering-based. Systems engineering offers a methodology for life cycle planning, which allows for the careful consideration of the full problem spectrum. This can be beneficially applied to many problem sets; however, as SE is an investment and comes with resource costs, it may not provide enough overall value to justify an SE culture implementation in all agencies. Those which cannot adequately support the SE culture initiative due to lack of resources such as organizational size, structure or budget limitations should consider other means to achieve necessary performance efficiencies, as partial implementation of SE practices yields minimal benefits or may even offer negative returns on investment. Despite strong evidence that SE application, when done correctly, results in a wide variety of tangible and intangible benefits to systems and product development projects, its returns are less and may not be justifiable when dealing with low levels of complexity. Systems engineering investment at lower levels, misapplication of SE or inconsistently application of SE to the project did not result in significant ROI and instead saw higher cost and schedule overruns and higher degree of performance issues.

Changing to an SE culture requires dedicated and sustained support from leadership and key stakeholders and significant resourcing of time, money and personnel (Fuller and Green 2005). Should honest analysis show that consistent support for the initiative cannot or is unlikely to be provided, it is best to not proceed with the culture change as full support is needed for the initiative to succeed. Of key importance is achieving change buy-in from the average employee, which may be managed by providing intrinsic motivators such as clear goals setting and continued communication, linking the change with its value to the service mission, actively soliciting employee participation in the initiative, providing training and other learning opportunities, and providing forums for public recognition and positive feedback aligned with the initiative. As part of the formalization process for the culture change, federal agencies should consider highlighting their culture when conducting human resource (HR) actions such as recruitment, retention, career

development and career path modeling. Once organizations have their SE culture aligned with their specific mission, vision and goals, and recruitment outreach and retention policies should emphasize these with potential and current employees. With recruitment, the intent is for hiring and outreach materials to resonate with like-minded potential employees, who will subsequently seek employment and embrace the prevailing organizational culture when hired. For all human resource (HR) actions, agencies should find ways to bake in the preferred culture to the hiring practices by aligning desired knowledge, skillsets and abilities with the new culture as much as possible. This allows agencies to formally integrate SE supportive requirements at the human resource level and provides a lever with which to require and evaluate employees' performance in the position's SE element. USA staffing now has an available systems engineering career competency model (SECCM) which can be integrated into position descriptions to better support SE-specific resourcing (Whitcomb et al. 2017, 16).

As federal agencies come under tighter budgetary restrictions, justifying a culture change initiative, which is likely to be viewed as an overhead or special project cost, requires excellent support reasoning built on value analysis. Systems engineering is well known in private industry and some federal agencies, but it is likely that some marketing and education regarding the value of SE may need to be done by the soliciting agency to receive approval from higher authorities. There are many directives, regulations and recommendations related to SE usage within the federal government and particularly the Department of Defense (DoD), which should be researched and included as part of the approval request to strengthen the soliciting agency's position. The common usage of SE within private industry and its value application to the government acquisition of outside products and services should also be used to justify the initiative.

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I. INTRODUCTION

Implementing a systems engineering (SE)–based culture may offer federal agencies a means to significantly increase performance efficiency while reducing overall cost to the organization. In an era defined by tight fiscal constraints, expanding mission requirements and a high debt ceiling, innovative, cost-effective solutions are required for federal agencies to meet the challenges of accomplishing more with less. Optimizing available resources and enabling complex problem solving and early risk mitigation are SE mechanisms for reducing costs and increasing performance efficiencies. To be effective, these mechanisms require a fully integrated, supportive organizational culture based on the theory and application of SE. Aligning organizational culture with desired strategic outcomes is a well-documented method for successfully achieving organizational goals, and an SE-based culture offers specific benefits well suited to address the critical constraints facing today's federal agencies.

A. LITERATURE REVIEW

This paper synthesizes available research regarding organizational culture and SE theory and application to examine culture change within the federal agency setting, establish the key attributes of an SE culture, evaluate the possible value of applying SE culture within federal agencies and outline a plan for successful SE culture change implementation.

The value and importance of aligning organizational culture with the organization's strategy in order to achieve better performance has been well documented and strongly validated by academic research. It is so well established as to be considered an organizational best practice and it is utilized and recommended by private industry titans such as Amazon's Chief Executive Officer Jeff Bezos (Gleeson 2017). Despite general academic and industry acceptance that culture should be used as a tool to support strategy, literature review reveals high rates of organizational culture change failure. The reasoning behind such failures is well documented by academic research, as are methods for successfully implementing an organization's preferred culture.

A review of the available literature regarding the value of an SE-oriented organizational culture is less conclusive. SE-related literature is widely available and academic review supports the view that SE application within an organization can provide strong benefits to a variety of product, system and organizational development areas. The value organizations can generate by utilizing SE is supported by decades of research and is so widely recognized that the federal government has mandated the use of International Standards Organization/International Electrotechnical Commission/Institute of Electrical and Electronics Engineers (IEEE) SE standards in defense acquisition projects. "IEEE 15288.1 is the primary document that will be tailored by Department of Defense (DoD) to define the government's requirements for SE. It will form the basis of the acquirer-supplier agreement defining the SE activities and tasks to be performed, the outcomes to be achieved, and the outputs to be developed" (National Defense Industrial Association [NDIA] 2015, 4). The DoD has a particularly strong interest in SE, as they are required to provide solutions to technical and engineering-based problems. Much of the literature focused on systems and product development applied-SE, and the benefits which could be achieved in terms of the project management golden triangle of performance, schedule and cost. Importantly, it was noted that the benefits of applying SE were proportionally tied to project complexity, and smaller returns were associated with small projects of lesser complexity. However, there is little academic research available regarding SE-specific organizational culture, what it might look like and what its overall value for an organization might be. There are few examples of SE culture within federal agencies, with National Aeronautics and Space Administration (NASA) being a notable exception.

When consciously engineered, implemented and supported by leadership to achieve desired organizational behaviors and drive performance, organizational culture can be a powerful tool with which to promote efficiency and effectiveness. All organizations, no matter their type or size, evolve distinct organizational cultures. Organizational culture is "the set of shared values and norms that controls organizational member's interactions with each other and with suppliers, customer and other people outside the organization" (Jones 2013, 9). Organizational culture is an internal influencing mechanism which affects the way an organization conducts its business. It contributes to the formation of business

processes, shapes the behavior of its members and ultimately affects the way the organization performs, (i.e., its success in providing goods and services). Implementing an SE culture within a government setting could potentially enable cost savings, schedule and performance benefits across a wide variety of government agencies.

An SE culture is defined as "an umbrella of shared values and behaviors that transcends the individual cultures of teams, departments, and disciplines—rooted in the appreciation of overarching system concepts and system relationships" (Carroll 2016, 4). An SE-based culture can reinforce performance and efficiency strategies by approaching goals from a systems perspective and applying SE concepts across the organization. Systems engineering is "an interdisciplinary team process aimed at creating successful systems. It starts by defining customer needs and functionality, before going on to create a holistic design. It considers both the business and the technical needs of [the] customer" (International Council on Systems Engineering [INCOSE] 2014). Systems engineering is rooted in holistic planning, analysis, risk mitigation, and managing complexity; all are factors which can help organizations improve their performance and gain efficiencies. In a time when most government agencies are facing sharp budget cuts and performance scrutiny, SE and accompanying support culture could prove an invaluable tool to help ensure available resources are utilized to their fullest value.

In a general sense, SE is a comprehensive approach to solving system-level problems. It is a life cycle mindset which may be applied to any system, be it a complex information technology system or a human organizational network, which makes it applicable to a broad spectrum of organization types. Application of SE principles provides organizations with the means to increase value throughout their organization by allowing them to accomplish more with less resources. It is highly correlated with fewer cost and schedule overruns, particularly as projects and systems increase in size and complexity. "Virtually every significant business or enterprise that creates products or services benefits from performing a wide variety of SE activities to increase the value that those products and services deliver to its owners, customers, employees, regulators, and other stakeholders" (Systems Engineering Body of Knowledge [SEBoK] n.d.). However, integrating SE processes and activities takes time, labor and money. To achieve value

through the use of SE, an SE mindset must become deeply ingrained into the foundation of the organization's culture. SEBoK states that "[establishing] and managing cultures, values, and behaviors is a critical aspect of SE, especially in the context of deploying SE within an organization" (n.d.). This ensures both that SE becomes the basis for decision-making and that it achieves a wide degree of application across all organizational levels. If SE integration into the organization's culture is not achieved, it follows that cultural alignment with strategy has not been successful. In such situations, the value achieved may be less than desired and the cost of utilizing SE may not be justified.

Successful implementation of an SE-based culture may be difficult to achieve and must be carefully approached. Engineering, implementing and supporting any desired organizational culture can be a difficult undertaking with high rates of failure noted within industry (Jørgensen, Owen, and Neus 2008, 10). Government organizations in particular may operate within constraints which require a government-specific culture implementation approach which varies from industry recommendations. Many culture change techniques advocated in private industry may not be available for government leadership to utilize due to the unique environment and constraints of the federal government, with issues ranging from budget constraints to its bureaucratic structure (Drumm 2012). If not mitigated, this disconnect may make it difficult for leadership to implement a significant change in cultural mindset within a government setting.

B. RESEARCH OBJECTIVES AND RESEARCH METHOD

This paper utilizes case and research studies to assess the value of implementing a system engineering culture within federal government agencies for the purpose of maximizing value. Traditional techniques for organizational culture change and possible limitations within the government setting are outlined. Key attributes of an SE culture are explored and value analysis findings for SE within organizations are presented. Government-specific, SE culture change implementation recommendations are offered, as tailored implementation plans can greatly increase organizational change success rate. Potential implementation risks unique to the government setting and accompanying

mitigation strategies are also reviewed. The paper concludes with a summary of findings and recommendations, as well as recommendations for areas of further study.

C. CHAPTER SUMMARY

Finding efficiencies and making the most of constrained resources is the new reality for federal agencies. Strategically aligning culture with organizational goals is a research supported method for attaining efficiency goals. Choosing to implement a system engineering-based culture should be a primary consideration for federal agencies seeking to optimize resources and strategically better their performance. However, careful analysis should be conducted to ensure the investment in the SE culture change is justified. While culture change implementations suffer a high degree of failure, following a federal agency friendly framework with recommendations specific to SE culture can help increase the odds of success.

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II. ORGANIZATIONAL CULTURE WITHIN FEDERAL AGENCIES

This chapter provides an overview of culture-shaping forces within the federal government, which often differ from private industry. Strategies for organizational culture change are discussed and then applied to the federal agency current cultural setting. The chapter also reviews possible methods for overcoming the unique culture change constraints faced by agencies and explores the concept of an SE-based agency culture, along with its attributes and requirements.

Today's agencies are faced with multiple workforce issues which affect culture and organizational performance, including lack of resources, workforce reduction measures, and budgetary constraints. Despite such issues, they must find innovative solutions to increase organizational efficiency in order to meet their requirements. "At the same time government is being…hamstrung by budget cuts, the public continues to ask the public sector to solve some of the toughest and most intractable problems" (Lauri 2013). High-performing organizations recognize the importance of aligning culture with organizational mission, vision, goals and strategies in order to optimize their resource usage and maximize efficiency. An organization's culture can be used as a tool by leadership to shape consistent and desired internal behaviors throughout all organizational levels. "Agencies that create new efficiencies in how they achieve their mission and maintain their organizational relevancy by adapting to change will be the ones that adopt [a]…culture to foster the innovative ideas and approaches to problem-solving that their employees regularly generate" (Eagle Hill Consulting n.d.). An organizational culture based on the theory and application of SE, a forward thinking and problem-solving methodology, may help agencies fully engage their workforce to maximize resource utilization, increase efficiency and ensure federal agencies remain technically competitive.

Agencies wishing to implement an SE culture must examine their current culture and be prepared to make necessary organizational changes to reach and maintain their desired state. To increase chances of implementation success, it is recommended that leadership follow a framework of organizational change best practices.

However, federal agencies are affected by different organizational constraints than their private industry counterparts. They are subject to specific rules and regulations which constrain funds expenditures and HR practices, have a high degree of public visibility, and are tasked to maximize fiscal responsibility. "The public sector faces both legislation that promotes transparency, and the general desire of the public and media to understand how 'their' money is being spent. The same simply does not apply to…Unilever, Shell or Ford" (Smith 2017). These environmental factors shape elements of federal agency culture and can limit the tools available to federal leadership to motivate culture change, especially in regards to tangible reward mechanisms commonly utilized by private industry. For example, a survey of over 800 public sector respondents found that "66% of public sector respondents rated rewards as very important or important, but only 4% indicated they have flexible rewards that are aligned to employee preferences" (Agarwal et al. 2018, 19). These environmental differences must be acknowledged and innovatively mitigated using available federal resources during a culture change initiative.

A. STRATEGIES FOR ORGANIZATIONAL CULTURE CHANGE

Culture is an important driver which helps shape business processes and employee behaviors to be more efficient and effective, which in turn increases organizational performance. Management expert Peter Drucker famously said that culture eats strategy for breakfast (Hyken 2015); it follows that integrating organizational culture with organizational strategy strengthens the probability of success. Though engineering a preferred culture has many benefits to the organization, it can be difficult to implement and maintain the new, desired culture. "Changing culture isn't as simple as identifying the new behaviors you want to see and articulating a new set of beliefs and values associated with these…. Most people won't change their behaviors until…they see this new behavior positively recognized and rewarded" (The Bridgespan Group 2012). Agencies must therefore take an informed, measured approach to culture change. "The organization must plan where it wants to go before trying to make any changes in the organizational culture. With a clear picture of where the organization is currently, the organization can plan where it wants to be next" (Heathfield 2017). Following a change framework or implementation plan can help ensure the organization addresses all necessary areas of change and increases

the odds of success; implementation plans are a critical component of change initiatives as they help organizations better justify their resource investment and outline a clear way forward.

There are a number of culture change strategies available to private and public organizations which can be utilized to better manage a culture change initiative. These strategies address several organizational and change management facets, including performing gap analysis between current and future state, engaging and motivating employees and generating sustained stakeholder support. As previously noted, public organizations such as the federal government face different constraints than their private counterparts; an SE culture change initiative within a federal agency must acknowledge these constraints and adapt plans to specifically address the federal agency environment.

Culture change initiatives fall under the umbrella of change management, of which there are many traditional process models. Major change management theories include Kotter's eight-step change model, Lewin's three-step process of change and the McKinsey 7-S Model for change (Cleverism 2015). Culture-specific change management models contain thematic variances but all contain similar core change principles. Culture is intentionally aligned with performance and strategy. To accomplish this, a cultural discovery phase is conducted where the organization's current culture is assessed. The discovery phase leads to a phase of cultural transformation, where processes and practices are put in place to lead the organization from the as-is environment to the desired to-be environment. Motivational tools are implemented by leadership to underwrite the change. Once this is accomplished, there is a phase of culture formalization or integration, where culture changes are codified within the organization in order to make them permanent.

Culture change begins with leadership-initiated culture discovery, or the assessment of the "as-is" current culture of the agency and the establishment of the desired "to-be" state. This requires careful analysis of the agency's mission, vision and goals. Gap analysis between the two states helps the organization plan an informed way forward to reach the desired state. The cultural transformation process involves the enlistment of key change agents, which are strategically selected personnel from across all layers of the organization. In order for change to be real and enduring, the entire organization must

participate and support the change. This level of support can be very difficult to generate, as culture is ingrained within individuals, and it requires effort to change. Resistance from some quarters is to be expected and must be strategically counteracted.

Champions for change can help disseminate and propel the change solution throughout the organization. Participation must be incentivized and supported with training and learning opportunities. Finally, the new culture must become codified within the organization through the transformation of policies, processes and practices to ensure their alignment with the culture and indoctrination into the organizational mindset. Throughout the culture change initiative and continuing into the sustainment phase, leadership and stakeholders must remain visibly engaged and enthused. Finding methods to motivate employees to participate in the new culture is of paramount importance to ensure change promulgation. Available methods of motivation will vary by the constraints of individual organizations.

B. CURRENT FEDERAL AGENCY CULTURE

Strong organizational cultures have several attributes in common (Coleman 2013). Key attributes include results orientation, high employee engagement, effective communication, purpose driven and adaptable to change. While organizational cultures will manifest differently within individual agencies, recent surveys have found that federal agency cultures tend to perform poorly in these areas; there are statistically significant negative performance gaps when compared to private industry counterparts (Rogel 2014). A 2017 national survey of U.S. federal employees found that just 34% felt they were fully engaged with their work (Lavigna 2017).

Federal government agencies are subject to a variety of environmental influencers which impact internal culture and may result in performance efficiency losses. These include a bureaucratic structure, changing political agendas, HR practices, and budgetary constraints (Manifredi 2014). These factors can contribute to the formation of a federal workforce with similar cultural trends affecting performance, such as low workforce morale, lack of employee empowerment and participation, and the reduced ability to adapt to change when compared with private industry counterparts (Eagle Hill Consulting n.d.).

These cultural trends align with less employee engagement, which is of critical importance since an unengaged workforce is on average 20% less productive than their more engaged peers (Lauri 2013). A 2012 survey of over 37,000 federal employees showed that those agencies with higher engagement also had better success meeting their goals, better workforce retention and less productive time lost to sick leave (Lauri 2013). Federal agencies are struggling to recruit, motivate, engage and retain employees. A 2016 General Services Administration survey of federal employees showed that 71% of respondents believed the federal government to be less innovative and open to new ideas than the private sector and 48% of respondents stated they were likely to leave their job in the next year (Eagle Hill Consulting n.d.).

1. Bureaucratic Structure

The federal government is a bureaucracy, "characterized by specialization of functions, adherence to fixed rules, and a hierarchy of authority" (Merriam-Webster n.d.). Bureaucracies are more apt to have rigid structures, be subject to top-down information flow and are often slow to adapt to change. Since bureaucracies are based on rules and a high degree of process, it can be hard for information, innovation and ideas to flow throughout the vertical structure of the organization. Top-down directives from leadership which are poorly communicated or supported may fail to catch on with employees at lower levels of the organization. Similarly, critical information and ideas formed at lower levels may never reach or be followed up by leadership. "Upward communications are poor in most hierarchical organizations because perception downward is poorer than perception upward. Add to that the 'filters' of management levels that dilute upward communications. As you go higher, the word gets more garbled, edited, or, even worse, eliminated entirely" (Harriman 1974). 79% of federal respondents in a 2018 Deloitte survey stated that they never worked directly with leadership on projects and strategic initiatives (Agarwal et al. 2018, 17) The resulting employee perception was that leadership did not fully understand issues within lower levels of the organization (and so failed to address them), that leadership did not value their ideas or input and that high performance would not be tangibly recognized or rewarded. This can lead to the formation of a frustrated federal workforce not fully engaged with the mission or in finding solutions and efficiency gains

to meet the challenges within the agency. “Government is also known for an almost obsessive reliance on rules and established practices. That’s deeply entrenched in the culture by years of static practices. It makes it very difficult to gain acceptance for new work methods. In successful businesses, the culture encourages employees to solve problems” (Risher 2017). Lack of flexibility makes it difficult to quickly adapt to changes or respond to challenges. To further complicate matters, in addition to internal agency hierarchy levels, the individual agency is part of a broader organization that reaches up to the executive office. 1.94% of the U.S. workforce is employed by a federal agency (Bump 2015). The overall organization is so large that many policies and processes crafted at higher organizational levels may be inapplicable or difficult to apply at lower levels. Information flow may be significantly constricted.

2. Changing Political Agendas

As a public entity, the federal government workforce is greatly impacted by the prevailing political climate. Shifting political priorities affects budgetary resourcing, raises the possibility of workforce shaping measures such as Reduction in Force, furloughs and pay freezes, guides regulation and policy design as well as mission priorities and requirements (Karmark 2017). Each fiscal year can bring substantial uncertainty, fear and anxiety to the federal workforce, as the executive and legislative branches of federal government work to pass the year’s budget and determine whether to raise the debt ceiling. Over the past six years, federal agencies have faced shutdowns, hiring freezes, workforce reduction measures, pay freezes, and smaller Cost-of-Living-Adjustments. Some agencies, such as the Environmental Protection Agency, have faced dramatic mission reprograming and agency restructuring. Such issues significantly impact morale and motivation within the organization and contribute to a negative organizational culture. “Morale, engagement, satisfaction—the words vary, but what we know is that highly engaged employees are emotionally committed to making their unit or organization a success. Companies with highly engaged workers have higher productivity, higher quality, lower costs and lower turnover” (Risher 2016). When looking to successfully implement cultural change, federal leaders must be mindful of outward environmental pressures which may be negatively

affecting workforce culture and look for methods to address morale issues within the agency.

3. Human Resource Practices

Federal agencies are subject to specific human resource practices, as outlined by the Office of Personnel Management (OPM). These practices guide the entire human resourcing process chain, and affect everything from talent recruitment, workforce retention, employee pay, through retirement. Federal agency HR practices must be consistent with the guidance, which leaves little room for flexibility. Existing practices make it difficult to align pay with performance, to offer pay commensurate with the private sector, or attract top talent through other incentive measures. This has led to a high-risk, critical shortage of skilled employee resources in key areas of employment within federal agencies and further reduced employee morale. "Because skills gaps within individual federal agencies—as well as across the federal workforce—can lead to costly, less-efficient government, the issue has been identified as the focus of the Strategic Human Capital Management Government Accountability Office (GAO) high-risk area since February 2011" (GAO n.d.). These issues mean the existing workforce is called on to fulfill more mission requirements with fewer personnel available to accomplish the work and which they may not have the skills or tools to fulfill. GAO further states that while "there are a number of tools that can help build a results-oriented culture within the federal government…developing modern, credible, and effective employee performance management systems and dealing with poor performers have been long-standing challenges for federal agencies" (n.d.). These issues affect organizational culture, as employees have little outward motivation to seek out efficiencies and innovative solutions. They may instead feel frustrated and disenchanted with the system and disengage if these cultural issues are not mitigated by other means.

4. Budgetary Constraints

The federal government is budgeted through congressional legislation and signed by the executive branch on an annual basis. Budgets across agencies may vary widely from year to year depending on the current political agenda and mission requirements. Federal

agencies must operate with specific funding rules and regulations. These constraints limit leadership's flexibility to address workforce recruitment, pay-for-performance, and the provision of training. They may limit leadership's ability to incentivize employee participation through monetary means and to fund non-mission essential initiatives aligned with increasing efficiencies (such as culture change implementations). "Agencies are facing strategic human capital challenges...Budget constraints will require agencies to plan their transformations more strategically, prioritize their needs, evaluate results, allocate their resources more carefully, and react to workforce challenges more expeditiously in order to achieve their missions economically, efficiently, and effectively" (GAO 2007). Budgetary constraints highlight the need for agencies to optimize resource utilization, but place limitations on mechanisms for achieving optimization.

C. SYSTEMS ENGINEERING TYPE CULTURE IN THE AGENCY SETTING

Federal agencies seeking to overcome the performance challenges presented by the current culture should consider a culture change initiative to better align culture with organizational mission and goals. Agencies should select the cultural orientation type which best supports their mission. Optimizing culture requires the agency to consider the type of culture which best supports their requirements and take internal steps to curate that orientation type to the appropriate level of maturity. Where the agency goal is to increase efficiency, mitigate risk, and optimize resourcing, implementing an SE-based culture should be a primary consideration.

It is important to recognize that implementing a particular culture type is about creating a supportive environment specifically oriented around the organization's primary purpose. For example, a sales culture is built to facilitate sales performance but does not require that all employees be salespeople or have a sales-based skillset. Similarly, an SE-based culture does not require an organization to be comprised only of systems engineers. Rather, employees throughout the organization are aware and buy-in to the organization's application of SE to better meet the mission and are engaged with their role in supporting that.

Systems engineering emphasizes holistic planning, taking a systems perspective and critical thinking skills. Its theory and processes provide a problem-solving framework with the goal of optimizing overall value; it can be applied to both technical and non-technical problem sets and can be profitably utilized by engineers and non-engineers alike.

> What do I mean about having a "systems engineering mindset"? At the most fundamental level, it's about taking an issue, assignment, task, and/or challenge and breaking it down systematically to produce a workable result.… For broad workforce consideration, it's more of a systematic approach philosophy than engineering discipline. At even a larger level, it's a critical thinking activity that can be applied to both technical and non-technical things in everyday life. (Lackey 2016)

Systems engineering is generally applied within teams for technical projects of various complexity to find best value solutions which are based on comprehensive analysis of the problem set. Project teams follow the SE framework to ensure the problem is understood, life cycle implications are well-thought-out and connections points are identified. During this process, many ideas will be considered which require decision making. It is at the critical decision-making juncture where culture especially matters and it becomes apparent that effectively deriving value through SE requires the support of the broader organization. Ideas are not resourced unless effectively communicated to leadership, who then make those resources available. The team is not empowered to communicate and move forward with ideas unless the organization has empowered them. Organizational support is not provided to the team and leadership unless the organization understands its role in achieving goals. Valuable insight may be lost if there is no input from other parts of the organization. The purpose of using SE is to help ensure the most value driven solutions move forward. However, the best ideas are rendered useless if they are not heard, appropriately resourced and otherwise supported.

1. Systems Engineering Support Culture Requirement

For those federal agencies utilizing SE approaches or considering implementing SE-based approach, it is essential that an SE culture be established to support these initiatives. Organizational culture is driven by the processes, policies, values, behaviors and norms established within the organization. The successful transition to an SE-guided

organization depends on creating a culture where SE principles and processes are integrated into the everyday mindset of individuals across the organization.

> Establishing and managing cultures, values, and behaviors is a critical aspect of SE, especially in the context of deploying SE within an organization…. Stable safety and process cultures are key to effective SE, and can be damaged by an overly-rapid pace of change, a high degree of churn…or by change that engineers perceive as arbitrarily imposed by management…. On the other hand, a highly competitive, adversarial or "blame" culture can impede the free flow of information and disrupt synergies in the workplace. (SEBoK n.d.)

Failure to integrate SE into the culture leads to the abandonment of SE approaches within the organization or such inconsistent and misapplied usage that it fails to provide value. "Ultimately, the main lessons are that when utilizing an SE approach, you must unify your teams with a common language and approach and provide a consistent, intuitive way to design more innovative products, validate that the products work as expected, and engineer product lines to maximize re-use" (Gold 2015). Unifying teams, establishing common languages, codifying processes and establishing team behaviors and norms which translate into consistent use of SE across the organization is the essence of culture engineering. Federal agencies under mandate or recommendation to incorporate SE need to be aware of the culture issue, as a high-level directive does not translate to successful implementation in the field unless the culture is carefully crafted to support the directive.

Culture change initiatives are difficult and are noted to have high rates of failure within industry. Following organizational culture change best practices is recommended to increase culture change success. As discussed earlier in the chapter, culture change initiatives within the agency setting are subject to a high degree of constraints which make the usage of many traditional culture change models contraindicated. Alternative culture change theories specifically for usage in the public setting must be explored prior to attempting to plan and implement an SE-specific culture.

2. Systems Engineering Cultural Attributes

Certain SE cultural attributes must be in place to create an environment which fosters innovative solution making and drives those solutions forward. These attributes

include communication driven from the bottom up, empowered decision-making, receptive leadership, and taking a systems perspective. A culture based on SE is curated to empower and engage employees, no matter their role, to think critically, look for risk and mitigation strategies, find value-driven solutions and communicate effectively with their peers and leadership. It also requires a receptive leadership body which seeks innovation, promotes effective communication throughout the organization, and which actively solicits and considers input from lower organizational layers. Systems engineering-based leadership effectively makes use of the knowledge, ideas and skills present within the organization. To do less is to fail to optimize utilization of organizational resources, of which personnel are perhaps most key.

All organizations, no matter their mission specifics, must accurately plan and effectively solve problems in order to meet their requirements. The ability to think through the full spectrum of a problem set, to identify and evaluate solution alternatives, and to find and mitigate risk enables a mindset geared towards finding innovative and value-sensitive solutions. “Improving SE efficiency and effectiveness can be the goal of cultural change. This kind of culture change encourages people to learn to think and act in terms of systems, organizations and their enterprises; and, to take a systems approach” (SEBoK n.d.). Members of an SE-based culture appreciate the merit of processes without being wholly defined by them, because the broader picture is always most important. When all levels of the organization, from grassroots workers through leadership, are trained to support a culture based on SE theory and processes, this type of problem solving is enabled at an organizational level and performance gains can be expected as a result.

3. Culture-Based Systems Engineering Failures

NASA is one of the few federal agencies which has a long history of using SE and which has actively built an SE-based culture to support its SE usage. NASA is required to solve complex technical problems and believes that “SE is a critical core competency in enabling the current and future success of NASA missions” (Williams and Derro 2008, 5). Despite this, NASA has suffered high-profile SE disasters. Consider the 2003 Columbia space shuttle explosion. The physical cause of the explosion was due to a piece of foam which damaged the shuttle’s left wing. The foam had been a known issue prior to launch,

and many members of NASA unsuccessfully attempted to interact with leadership to remedy the problem. The Columbia Accident Investigation Board later determined that "Cultural traits and organizational practices detrimental to safety were allowed to develop…Reliance on past success [was used] as a substitute for sound engineering practices…Organizational barriers that prevented effective communication of critical safety information were among problems found" (Howell 2017). This example highlights the necessity for a fully integrated SE culture; most particularly, the need for open communication channels between a knowledgeable ground floor and a receptive leadership body. Without such a channel, critical information cannot flow or get the attention required. Scenarios where critical information is not received or is ignored by leadership are to be avoided at all costs. It is not enough for a few resources within the organization to think critically and attempt to execute their mission accordingly. To attain value through SE, there must be enough resources engaged and supportive of the methodology; a certain critical mass which must be reached throughout the organization in order to realize performance gains, particularly within management and leadership levels. Without full cultural integration at all layers, it would be difficult to provide the necessary comprehensive support required to propel optimal outcomes, as well as to avoid unfortunate ones.

D. CULTURE CHANGE CONSTRAINTS SPECIFIC TO FEDERAL AGENCIES

Moving to an SE culture requires a culture change initiative. There are many frameworks available for federal agency usage to increase the probability of culture change success. However, traditional techniques for implementing culture change make the implicit assumption that the organization has complete control over its internal environment. For example, traditional models assume that should the organization choose to implement financial-based incentives to facilitate its culture change initiative, it is free to do so (within the confines of the budget and strategic goals). Likewise, though traditional models certainly do not assume such actions to be easy or without significant use of resources, they do assume that changes to organizational structure, implementing training programs, or recognition programs are all internally achievable by the organization. That

is, there is no roadblock preventing them from choosing to make use of these traditional culture change tools. However, that is often not the case for public organizations like the federal government, which are subject to external and internal agency bureaucratic constraints. Public organizations may be much more limited by rules and regulations, which make it difficult for them to follow traditional change management models. "Public sector changes may not be more difficult than those in the private sector, but they are different…The unique thing about the public sector is that change takes place in a fishbowl and the agents of change are neither the biggest nor most aggressive fish in the bowl" (Cunningham and Kempling 2009, 330). Traditional culture change models do not always make a distinction between public and private organizations. When implementing a culture change initiative within the public setting, it is important to be aware of possible model limitations and to seek out change models which specifically provide a framework compatible with the unique environment and constraints experienced by public organizations such as the federal government.

1. Federal Government Constraints

All organizations are subject to external laws and regulations. However, public sector organizations such as the military and federal government agencies are more likely to be subject to internal rules and regulations which place additional constraints on their ability to implement change. "In the public sector frequent political agenda changes, legislative rather than market-driven goals, and insufficient allocations of financial and human resources often hinder change" (Rusaw 2007, 351). In the case of culture change initiatives, there may be rules, regulations and other bureaucratic policies in place within the public organization which dramatically limit its ability to utilize standard culture change tools.

The structure of the public organization plays a large role in determining the extent to which it is affected by these constraints. The federal government is a clear, well defined vertical organizational structure. "Vertical organizational structures are characterized by few people at the top and increasing numbers of people in middle management and lower level positions.…Vertical structure is the classic bureaucracy and is epitomized and originated in one of the oldest government functions: military command" (Feigenbaum

n.d.). Decisions at the top of the federal government vertical structure most likely affect agencies far lower in the structure because there may be very little direct communication between the two; the decisions made at the top levels may not be well aligned with the goals, mission and vision of the lower level agency.

Those federal agencies at the bottom of the vertical structure may be much more constrained in the culture change tools they can utilize, as they may have limited decision making and resources allocation power. “Legal barriers, such as union agreements and complicated policies…funding [restrictions], and entrenched bureaucracy resigned to ‘waiting out’ change initiatives, represent just a small portion of the challenges often faced by government leaders. Federal bureaucracy prevents many leaders from even attempting to boost mission performance by addressing culture change” (Forsythe, Baker, and Stamilo 2016, 5). This can affect federal agencies’ ability to implement some of the basic recommendations of culture change initiatives, such as realigning organizational structure, creating financial incentives and implementing training and reward-based programs, as they may be prohibited or greatly constrained by public policy. For example, over 70% of the federal government is subject to the General Schedule (GS) pay structure (GoGovernment n.d.). The GS pay structure consists of 15 grade levels with 10 pay steps or wage grade increases (WGI) contained in each grade (OPM n.d.). Employees are hired in with a pre-set pay plan, and if they meet basic acceptability levels, they will automatically receive annual pay increases according to that plan. There is little flexibility for federal GS leadership to set up financial incentive plans due to limitations of the GS system. “Pay and performance under the GS system are not very well linked. The WGIs reflect no link between pay and performance. All other things being equal, a mediocre employee will receive the WGI as fast as a better-performing colleague” (Montoya and Graham 2007, 21). Though there are some performance incentives available for federal managers to implement, such as quality step increases, and performance awards, they are greatly limited and take much documentation effort on the part of the manager to bestow on individual employees. For example, managers have the discretion to assign lower performance awards to lower performing employees; however, performance awards are generally no more than 2% of the employee’s salary (OPM n.d.). Assuming the same base

salary of $50,000, an employee receiving the lowest performance rating might receive a 0.5% annual award of $250.00 pretax, while an employee receiving the highest performance rating might receive a 2.0% annual award of $1,000 pretax. The difference between the lowest and highest annual performance financial incentives may be so small that it fails to be a performance motivator for individual employees. Due to existing HR regulations and processes, it may be equally difficult for managers to penalize poor performance, leading to high employee job security even in cases of very poor job performance (McPhie and Rose 2009, 4). Due to this, some culture change mechanisms easily available to private industry, such as realigning or removing a resistant employee persistently impeding the culture change may not be available to the federal agency and thus cannot be used to motivate employee participation with the desired change.

2. Public Motivation Theory

One of the primary tenets of culture change theory focuses on the issue of employee motivation. “Work motivation is a set of energetic forces that originate both within as well as beyond an individual’s being, to initiate work-related behavior and to determine its form, direction, intensity, and duration” (Pinder 1998, 11). In order for culture change to be successful, there must be grassroots support and sufficient employee motivation to buy in to the change. Traditional motivation tools focus on creating financial incentives, recognition and reward programs, training and learning opportunities designed to incentivize desired behavior, (i.e., to willingly participate in the changes necessary to build and sustain the desired culture). The ability to motivate employees in the public sector is somewhat limited. Traditional motivational practices routinely used in the private sector, such as financial incentives and employment security factors, are of limited use to federal agencies due to government HR mechanisms and policies. These constraints require federal agencies to use other, public sector-based means to motivate employee participation with the desired culture change. Public motivation theory provides alternate motivation techniques to facilitate change within public sector organizations.

a. Extrinsic versus Intrinsic Motivation

Public motivation theory makes use of the principles outlined by Self-Determination Theory, which distinguishes between extrinsic and intrinsic motivation factors. "Intrinsic motivation is the motivation to do something for its own sake…. Extrinsic motivation is the motivation to do something in order to attain some external goal or meet some externally imposed constraint. Feelings of self-determination, control, and satisfaction have long been linked to an intrinsically motivated state" (Hennessey et al. 2014, 1). Extrinsic motivators in the workplace include salaries, promotions, job security, working conditions, and other tangible external reward-based incentives. Intrinsic workplace motivators, on the other hand, consist mainly of intangible benefits to the employee such as job satisfaction, feelings of pride and accomplishment in their work and being publicly recognized for excellent performance. A prime public motivation theory hypothesis is that the public sphere has limited ability to utilize extrinsic motivation factors and must therefore focus on creating an organizational environment which enables intrinsic employee motivation. "Government agencies usually can't provide performance incentives like large pay raises and bonuses; or perks like stock options, fitness center club memberships, and car services. Faced with limited ways to reward and recognize performance, federal agency leadership must focus on agency mission and impact, and also provide nonfinancial recognition" (Lavigna 2014). Federal agencies have less means than private industry to utilize extrinsic motivational factors, as federal HR practices and organization structure greatly limit leadership's ability to set up performance-based pay and award systems. These also make it difficult to realign or remove non-conforming and resistant personnel. Without financial incentives or job security motivators at their disposal, employee engagement practices become key.

b. Public Service Intrinsic Motivator Recommendations

Change recommendations for implementing intrinsic motivators within federal agencies include through employee engagement include (a) clear goal setting by leadership; (b) stressing the value and positive mission impact of the desired change; (c) generating employee engagement through shared decision making and solicited participation in the change process; (d) providing learning and training opportunities

related to the desired change; and (e) giving positive employee feedback and public recognition to employees actively participating in the change. A further consideration for federal agencies implementing culture change is to consider their hiring practices. A central hypothesis of public motivation theory is that much of the public workforce specifically sought public employment over private employment because they were motivated by intrinsic factors traditionally associated with public service, such as a desire to serve their communities. "[Primary] motivators for public-service employees are the interests that attract them to public service. These interests are likely different from those of people who self-select into the private sector…. [Those] who seek to manage the affairs of the government have a primary interest in helping to realize this common good" (Perry 2000, 484). A 2007 empirical study of 807 public sector managers and professionals supports this hypothesis. "[The] degree of mission valence and extrinsic rewards that public employees experience at work is consistent with expectation...These public employees reported placing considerable importance on the goals of their organization while simultaneously noting relatively lower levels of extrinsic rewards" (Wright 2007, 59). When planning for culture change initiatives within federal agencies, emphasis should be placed on the unique intrinsic motivational factors to be capitalized on within the agency workforce. Extrinsic motivating tools should still be used to the extent possible, as they hold an effective place in culture change initiatives. However, their implementation challenges and limitations must be planned for and overcome by other, more intrinsic means within the federal agency setting.

E. CHAPTER SUMMARY

The federal government's unique organizational environment affects the formation of its current culture and results in motivational constraints which differ from those of private industry. These constraints can affect rates of federal employee engagement and may result in a culture which fails to motivate high employee engagement and performance. An SE-oriented culture may provide agencies with a way to overcome negative cultural attributes and provide a framework to seek performance gains and efficiencies actively. To move to an SE culture requires a culture change initiative. Culture change best practices stress the use of both extrinsic and intrinsic motivators to engage

employees with the culture change initiative, with most research supporting the heavy use of extrinsic motivational tools. Due to constraints, federal agencies have limited extrinsic motivational tools at their disposal. Federal agencies will instead need to focus on utilizing intrinsic motivation tools to the best of their ability, based on the concepts of public motivational theory.

III. SYSTEMS ENGINEERING ORGANIZATIONAL VALUE ANALYSIS

To optimize resources and maximize efficiency and effectiveness, federal agencies should consider implementing an SE culture. For most federal agencies attempting to move forward with an SE culture initiative, it is likely that a business case or value analysis will need to be conducted which supports the premise that SE application can provide efficiencies for the agency. This chapter will review available SE case studies and research to provide a value analysis of SE application and determine the organizational attributes which signal that SE may provide significant benefits. Organizational-related implications of the analysis will also be discussed.

The determination that an SE culture is an optimal fit for the agency requires careful analysis to justify resource investment. Accurate value assessment requires that the agency understand the key functions, processes and attributes of SE itself and the overall organizational value which may be derived through application of SE activities and support functions. Systems engineering is "an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem" (INCOSE 2018). At a very high level, it is a life cycle-based approach to problem solving which uses a scalable, structured methodology to ensure a best value outcome is achieved. By considering the full life cycle early in the solution-finding process, using a structured methodology to avoid invalid assumptions and the omission of important considerations, proactively managing risk and generating more thorough requirements, SE processes help control costs associated with system or product implementation and sustainment. "By using the SE approach, project costs and timescales are managed and controlled more effectively by having greater control and awareness of the project requirements, interfaces and issues and the consequences of any change…. Research shows effective use of SE can save 10–20% of the project budget" (Smith and Brown 2014, 3). The SE approach allows

organizations to provide their products and services faster, better and at lower cost. The fundamentals of the system engineering life cycle approach are shown in Figure 1.

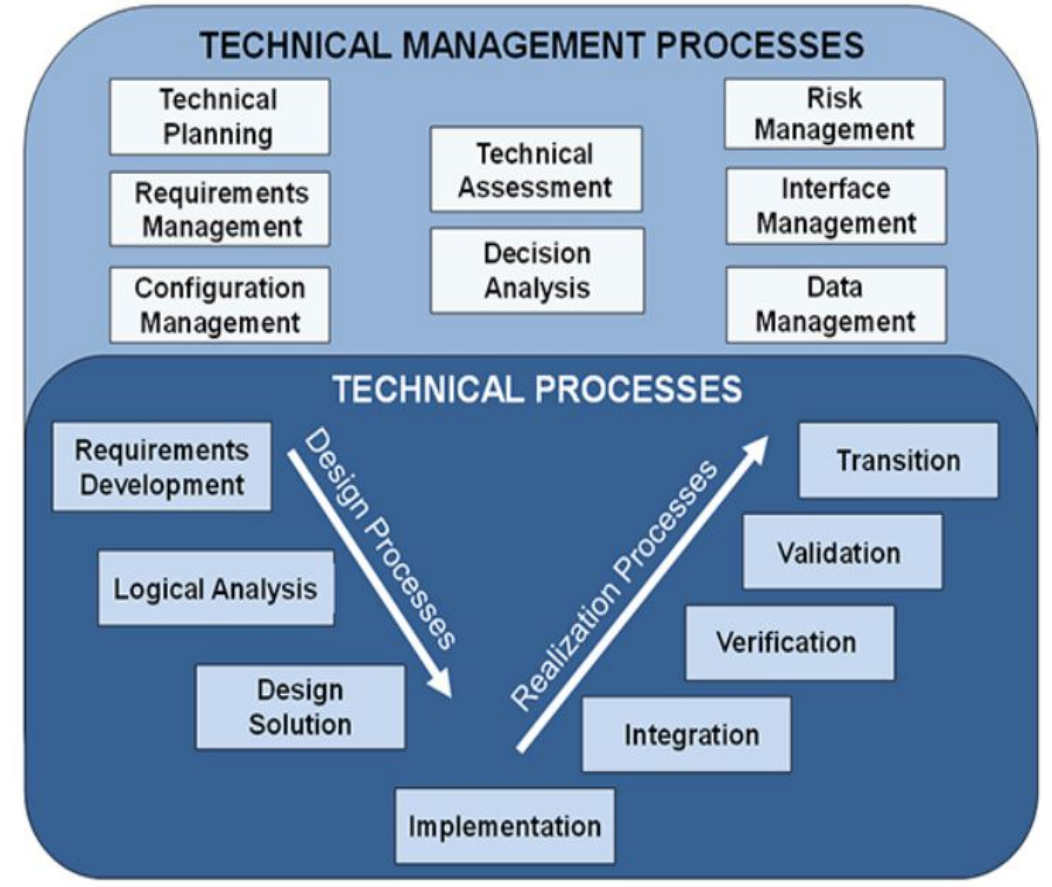

Figure 1. Systems Engineering V-Model. Source: Defense Acquisition University (2017).

A. ASSESS SYSTEMS ENGINEERING RETURN ON INVESTMENT

Implementing an SE-based culture takes organizational time, money and energy. Incorporating SE just at the project level continually requires additional resources. Federal agencies need to be able to justify such an implementation and SE resource allocation by highlighting the expected ROI of applying SE within the organization. Though widely adopted throughout DoD and some private industry, the explicit, tangible value of SE can be difficult to enumerate. Much of the research touting the benefits of SE is based on

heuristics and other qualitative factors, but few actual business case studies have been conducted to quantitatively prove these assertions. This is thought to be due to the rather invisible nature of SE if done correctly. "[There] is relatively little quantitative evidence of the impact and value of SE. Everyone can see the SE costs, such as the labor applied and the time allocated in the schedule. The benefits of SE, however, may be less identifiable" (Elm 2013). As SE is a critical thinking discipline where much of the returns are based on risk and issue mitigation, applying it successfully results in many difficult to quantify but very valuable returns such as less rework, fewer failures, and on-schedule delivery (Elm 2013). It can be difficult to measure how much of those returns are attributable to the utilization of SE practices or other factors or to put a dollar figure on those returns. Meanwhile, SE-related failures are quite visible and may lead to abandonment of SE application within the organization. The costs of applying SE are also highly noticeable, as it requires tangible resource investments of time, money and personnel. Organizations considering applying SE within their organization must look at both the tangible and intangible benefits associated with SE, as well as the reasons behind SE-related points of failure, to conduct a full-spectrum value analysis of SE.

1. Qualitative Benefits of Applied Systems Engineering

Performance gains were demonstrated in diverse areas and included developing higher quality products and systems and achieving higher rates of customer satisfaction with less rework and less reprocessing. Correctly applied SE resulted in far fewer performance failures (Shepherd 2015). Of much interest were the performance gains noted for regulatory compliance and security focus areas. "The connection between complexity, security and quality shows the value SE brings to development of a complex system. Therefore, SE is the most cost-effective discipline to ensure security is designed into a system" (Lyon 2012, 3). By adding security and regulatory requirements early in the life cycle, they become an integral part of the design process rather than an afterthought. This results in the creation of more highly secure products and systems, with fewer security holes and paths to security failure. Addressing regulatory concerns early in the life cycle also allows them to be integrated as a fundamental design aspect of the product or system. Regulations often change or evolve over time, so addressing existing requirements from an

SE perspective can allow for better planning towards future requirement integration. The SE method is something "developers can follow to integrate SE activities with regulatory compliance activities to provide a more cohesive approach to developing effective and safe…devices" (Maheshwari et al. 2015, 16). Table 1 shows a high-level summary of SE benefits for performance, cost, schedule, security and regulatory compliance areas.

Table 1. Summary of Systems Engineering Benefits across Area of Focus

Systems Engineering Benefits	
Area of Focus	Benefit Description
Performance (Quality)	Higher SE investment is positively correlated with greater satisfaction of requirements. Requirements are more likely to be more effective in matching the problem space and output is more likely to meet customer expectations. Quality measures higher with fewer rates of failure. Rework is reduced. SE ROI increases with complexity of product or system.
Cost	Greater level of SE investment is positively correlated with smaller and fewer cost over-runs and lower Total Ownership Costs (TOC). Most system and product costs are locked in early in development. Applied SE can help decision makers consider the life cycle costs of the product or system early in the development process and enable selection of less costly alternatives. Early risk detection and mitigation is also a factor in cost savings.
Schedule	Smaller and fewer schedule over-runs. More projects reach successful completion during required timeframe.
Security	Security components, including cybersecurity, are integrated into the product or system design process early in the life cycle, enabling tighter security measures to be baked into the system at lower cost than non-SE driven projects.
Regulatory Compliance	Regulatory compliance is considered early in the product or system design life cycle, enabling design to meet existing regulatory requirements and plan for the addition/changing future requirements. This is achieved at lower cost than non-SE driven projects.
Enterprise	Applies SE principles, concepts, and methods to the planning, design, improvement, and operation of an enterprise. Creates value through resource optimization (people, knowledge, assets) across the enterprise.

2. Qualitative Points of Systems Engineering Failure

Review of SE literature found several examples of SE failures at both the project and organizational level. Some well-known SE projects are associated with the United States federal government and military. These include the Hubble Space Telescope, Delta 180 Powered Space Interceptor and the X-33 Reusable Launch Vehicle (Slegers et al. 2012,

74–82). In all these cases, system engineering practices had been applied and there were rules, policies and procedures in place within the organization mandating the usage of SE and its usage had been codified in to the organizational culture. “The security and many aspects of a nation’s economic process depends heavily on how well its aerospace, defense and energy systems perform…Process and controls are instituted or improved; accountability reviews and milestones are defined and historical experience is incorporated into organizational culture and training” (Slegers et al. 2012, 74). Despite this, all these projects experienced high profile failures in SE. Literature review shows that the common thread for these failures was not due to weakness within the SE methodology, but rather that the organization failed to support the SE effort with adequate resources of time, labor and money.

An additional factor often found in large, bureaucratic organizations was related to the implementation and reliance on too many or too stringent processes and controls. “[While] process is necessary, human behavior seems to evolve so that process, when not watched very carefully, seems to remove self-accountability, self-thinking and retrospection. In all successful projects, there is a level of personal commitment, integrity and accountability, whether it is about engineers or technicians” (Slegers et al. 2012, 80). These failures point to a fundamental misunderstanding of how SE can be used to achieve success. Systems engineering application must be consistently supported throughout the organizational layers to be useful. That is, leadership and management must provide sufficient resources for operators to apply SE at the necessary levels to achieve positive results. Less than sufficient resources negate the value of SE. Processes and policy are not a stand-in for the critical thinking and problem-solving mind-set which lies at the heart of the SE method. Over reliance on process by leadership, management and operators, without applying critical thinking during the process and when reviewing the output, negates the benefits of SE.

3. Systems Engineering Quantitative Value Analysis Case #1

One of the largest quantitative case studies conducted on the subject was performed in 2012 by Joseph Elm of NDIA. The study consisted of 148 participants from defense and non-defense contractors, as well as U.S. and non-U.S. system developers. The purpose of

the study was to measure objectively the cost, schedule and performance project influence when applying SE. The case study found that projects applying SE showed dramatic positive results in all areas over non-SE projects, and that returns grew in tandem with project complexity. For those projects with low project complexity and lower SE investment, 23% of projects were considered highly successful versus a 52% high success rate for those low complexity projects with high SE investment. For high complexity projects, the success rate for low SE projects dipped to just 8%, while projects which invested heavily in SE soared to a success rate of 62%. Projects were considered a success according to whether they met budget, schedule and performance targets as well as satisfying technical requirements. "Measures of project performance included: Earned Value Management System data (e.g., cost performance index and schedule performance index), percent of requirements satisfied, changes in budget, changes in schedule, perception of customer satisfaction, and…[that respondents provided] available data for all relevant measures" (Elm and Goldenson 2012, 5). See Figure 2.

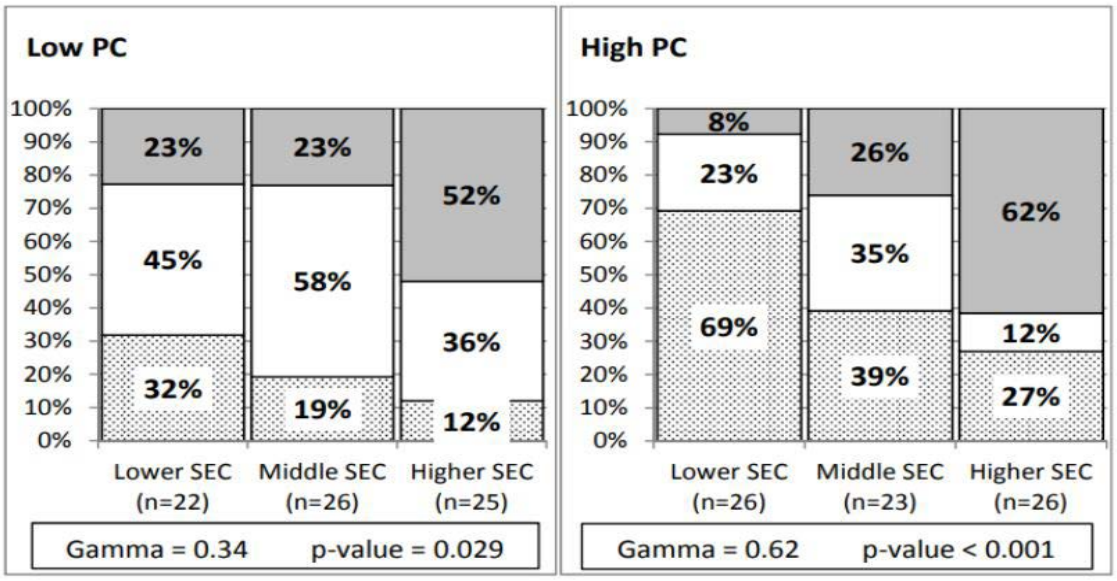

Figure 2. SE Success Rate by Project Complexity and Investment Level.
Source: Elm and Goldenson (2012).

Gamma measures the strength of the relationship between the variables project challenge (PC) level and level of SE capability (SEC). Gamma is measured between -1 and +1; a Gamma measure of 0.34 and 0.62 (low project complexity and high project complexity respectively) indicates a very strong relationship between the two variables. P-values < than 0.05 indicate that the null hypothesis (that the relationship between variables is not very strong) is not true and can therefore be rejected. The case study supports the widely-used heuristics that SE delivers significant cost, schedule and performance benefits when adequately resourced and correctly applied. An important aspect of the case study was that the degree of SE successfully applied was directly proportional to the level of project success attained. If SE was applied partially or incompletely throughout the process, the returns on system engineering application were diminished. Elm's analysis supports a required investment of approximately 15–20% of project cost in order to maximize SE benefits. Their analysis further showed that many organizations attempting SE application were only investing between 3–8% of project cost.

4. Systems Engineering Quantitative Value Analysis Case #2

NASA is one of most visible organizations using SE to achieve optimization of resources, lower projects risks and execute highly complex systems and products at best value. NASA is a federal agency which has long been the target of budget cuts and continually charged with accomplishing more with fewer resources. After experiencing some highly visible projects failures, including massive cost and schedule overruns for the International Space Station, Global Positioning System and other aeronautics projects, NASA conscientiously engineered a highly developed SE culture support by all organizational levels and well supported by organizational processes and policies (Stockman, Boyle, and Bacon 2010). NASA typically invests between 10–15% of project cost into SE efforts, much of which is frontloaded early in the life cycle. As reported by Honour in 2013, NASA conducted a study regarding SE application to 32 NASA programs. The study found that investment at 15–17% of project cost was most effective at minimizing program overruns. Projects at more than 17% investment saw diminished returns and did not appear to justify the extra investment. Cost overruns at programs with 0% SE investment were 6 times higher than programs with 15% SE investment; investment

at the 5% level saw program cost overruns 3 times higher and 10% investment saw overruns which were 2 times higher than 15% SE investment.

The study highlights an important point regarding SE investment. As front-end investment in SE grows, project cost overruns are reduced. It is not known how project complexity was factored and there is wide dispersion of data in the study; however, NASA's data supports the perspective that no or little investment of SE into complex projects is closely associated with high levels of project cost overruns. As investment is increased, greater ROI is experienced, with optimal results occurring near 15% investment.

5. Systems Engineering Quantitative Value Analysis Case #3

A 2008 study by Boehm, Valderi and Honour regarding the SE application influence on a complex software system development process noted mixed results. Return on investment was rated as high as 8:1, with up to 92% increase in performance factors. However, this was true for cases of large scale and complex system development projects. Return on investment was much lower on smaller, less complex projects and improved performance factors by only 18%. The study further found that significant SE investment with very small development project "is counter-indicated. This is particularly true for small software projects that are already using in excess of 15% [SE effort]" (Boehm, Valderi, and Honour 2008, 12). As was noted in the previous cases, SE was less effective with smaller projects with reduced complexity. Overall, study authors recommend investing in SE, as long as the investment is made at project appropriate levels. "These results strengthen the argument for the value of SE by providing quantitative evidence that doing a minimal job of software SE significantly reduces project productivity" (Boehm, Valderi, and Honour 2008, 12). Little to no ROI was seen in projects which incompletely applied SE or applied SE at less than 10–15% of project cost.

B. SYSTEMS ENGINEERING VALUE ANALYSIS RESULTS SUMMARY

Case study and literature review support conventional SE heuristics and present consistent quantitative findings regarding the value of applying SE to product and system development projects. Investment at 10–15% of project cost was consistently found to maximize investment. Value was optimized in a variety of ways, including budgetary

savings, lower TOC, schedule gains and operational gains. Higher ROI strongly correlated with increasing project complexity. Systems engineering investment at lower levels, misapplication of SE or inconsistently application of SE to the project did not result in significant ROI and instead saw higher cost and schedule overruns and higher degree of performance issues.

This finding highlights a key issue regarding SE value. Value optimization from SE techniques relies on consistent and correct utilization of SE practices throughout the project. In order for this to occur, organizational stakeholders across all levels must actively be involved in and support the usage of SE, (i.e., there is a cultural support requirement for SE application to be successful). Sufficient budgetary and personnel resource allocations must be made available. Operational employees must be supported by management and leadership in SE endeavors. Planning to incorporate sufficient SE should be a natural part of project planning throughout the organization and SE should be baked into organizational policies and processes. Findings demonstrates the need to align culture with SE strategy in order to receive the full benefits of SE application. If this is not done, investment in SE will not be optimized and may even contribute to project cost-overruns.

C. ORGANIZATIONAL IMPLICATIONS OF SYSTEMS ENGINEERING VALUE ANALYSIS

Based on the results of conducted quantitative analysis, SE appears to offer the most benefit to organizations which often have projects with high levels of complexity. To fully benefit, the organization must integrate a supportive SE culture which fosters SE to necessary levels. However, that is not to say that all projects must be technically or engineering-based. Systems engineering offers a methodology for life cycle planning, which allows for the careful consideration of the full problem spectrum. This can be beneficially applied to many problem sets; however, as SE is an investment and comes with resource costs, it may not provide enough overall value to justify an SE culture implementation in all agencies. Those which cannot adequately support the SE culture initiative due to lack of resources such as organizational size, structure or budget limitations should consider other means to achieve necessary performance efficiencies, as partial implementation of SE practices yields minimal benefits or may even offer negative

returns on investment. Despite strong evidence that SE application, when done correctly, results in a wide variety of tangible and intangible benefits to systems and product development projects, its returns are less and may not be justifiable when dealing with low levels of complexity. Initial implementation of SE culture into the organization comes with its own cost, while incorporating SE into projects will require continuous further investment. Organizations must carefully consider their resources, operations, goals, mission and vision to determine if SE application provides them with the type of returns they seek. If it does not, then an SE culture type would not be an appropriate type for the agency to implement in order to achieve efficiency gains.

D. CHAPTER SUMMARY

With the right level of cultural support in place, implementing SE practices and accompanying SE culture could benefit a large variety of organizational types, including those organizations which may not consider themselves to be strictly engineering or technically-based. Implementing a system engineering-based culture does not require an organization to be wholly composed of systems engineers. It has adaptable, complementary characteristics and attributes applicable to different functions within the organization; functions are synergistically performed to provide a supportive, SE-based culture within the organization as a whole. Additionally, SE has a maturity component and does not require an "all or nothing" mentality. Organizations may implement an SE culture at the appropriate maturity level to maximize value to their business. It creates value within the organization by applying a critical thinking-based framework to a variety of problem spaces which might otherwise go unanalyzed.

IV. SYSTEMS ENGINEERING CULTURE IMPLEMENTATION WITHIN THE AGENCY SETTING

This chapter outlines the necessary planning and implementation activities necessary for a federal agency to move through an SE culture change initiative. Specific recommendations for curating an SE culture are provided and the critical role of leadership in underwriting and sustaining culture change is discussed. Key risk management activities should also be integrated into the culture change process.

The actions outlined in the implementation plan "move a strategic plan from a document that sits on the shelf to actions that drive business growth. Sadly, the majority of companies who have strategic plans fail to implement them…. The strategic plan addresses the what and why of activities, but implementation addresses the who, where, when, and how" (Olsen 2018). As with any major strategic change, culture change initiatives are subject to a high degree of failure. Studies show that strategic change failure rates may be as high as 67% (Bustin 2014); however, such high failure rates are mainly attributable to poor planning (failing to translate a strategic plan into actionable implementation deliverables) and lack of organizational support. Mitigating those types of risks is one of the many benefits which can be achieved through applied SE during the formulation of culture strategy.

Applying systems thinking and associated SE concepts to organizational development actions such as culture change allows for a comprehensive change approach enabling big picture thinking, long term planning founded on real data from within the organization and its subsequent analysis, early risk detection and risk mitigation. "Systems thinking is…designed to tackle complexity and produce significant results as we strive to understand and guide organizational change. It is a structured approach that emphasizes examining problems more completely and accurately before developing and implementing solutions" (CPS HR Consulting 2012, 3). This paper proposes adapting existing culture change models to fit the unique constraints and environment of the public sector and applying systems thinking and associated SE concepts to model recommended courses of actions to increase the chances of culture change success.

A. SYSTEMS ENGINEERING CULTURE IMPLEMENTATION PLANNING ACTIVITIES

Implementing an SE-based culture within the federal agency setting requires modifying traditional culture change models to address the specific constraints applicable to the public sphere. A significant portion of those constraints relate to the specific issue of generating employee motivation and the unavailability of traditionally recommended extrinsic motivational tools within most federal agencies. During the cultural discovery phase, each individual agency must take a clear look at their current culture, their business strategies, their resources and constraints in order to plan their best way forward. Based on the results of discovery, a plan for transformative change is created. A change implementation plan is the organization's engine powering culture change success and describes specific courses of action to be followed in order to achieve their desired culture state. Risk identification and mitigation play a large role in strategic planning and implementation. Finally, the culture change initiative concludes with steps to integrate the new culture through formalization of support policy and process changes.

1. Identifying the Need for Cultural Change

The culture change initiative should begin with leadership identification and agreement regarding the need for culture change; in this case, to change to an SE support culture. Often, identifying the need for change is driven by external triggers such as geo-political events, regulation changes, and changing customer expectations, as well as internal triggers such as operational performance problems, budgetary and resourcing issues and changes in leadership and/or key personnel (Decision Innovation n.d.). The agency may be underperforming, have trouble operating within their budgets, unable to meet customer demand or all of the above. Such agencies should be retooled to enable better performance and optimize resources to better meet demand. The agency must examine its existing mission, vision and goals to ensure they align with the current external and internal factors the organization is facing. If the existing mission, vision and goals are still applicable, but the organization is not performing to them as desired, the organization must examine its internal environment to find causes for variance between actual and desired performance. An SE culture change initiative results if leadership identifies the

organizational culture as a key, currently underutilized tool in achieving alignment with mission, vision and goals and further determines that an SE-based culture is an appropriate strategic fit. The agency may also find that its existing mission, vision and goals do not align with their current situation and seek to realign them to an SE culture in order to better serve their business strategies. “Strategy is the approach chosen by an organization to achieve success or a competitive advantage. Thus, the culture will be an asset for an organization if it encourages the behaviors which support the organization’s intended strategy” (Cabrera and Bonache 1999, 55). In such cases, it is critically important to evaluate whether the current organizational culture also aligns with the changes being made, and if not, take steps to bring them into alignment. Such alignment requires that leadership clearly and objectively determine the desired state of the SE culture-based on the established mission, vision and goals of the organization. However, as changing culture requires considerable resource investment, the entire process of determining the necessity of culture change should be based on careful analysis of the organizations’ current state versus desired state (gap analysis) and a cost-benefit analysis of moving from current to desired state utilizing a culture change framework. An SE culture change initiative should not be undertaken unless performed analysis supports one, as discussed in Chapter III.

There are several factors specific to federal agencies which should be considered at this stage. Executive leadership is generally the driver behind culture change initiatives. However, within the federal government, there are many levels of leadership. Executive leadership of the agency exploring the culture change initiative may need approval from higher levels of authority. As federal agencies are part of an enterprise type organization, participation may be needed from other enterprise components to fully realize the value of the initiative. Such participation requires solicitation from the originating agency and buy-in from the potential participant. Conducting culture change activities, even at the exploration and planning stages, consumes resources which could be used or are currently allocated elsewhere. Some agencies without the manpower or necessary skillsets may consider contracting for SE subject matter experts from private industry to conduct the exploration phase and create the business case analysis, should they have the budgetary resources and approvals to do so. Those without budgetary and manpower resources to

conduct these activities may find themselves severely limited in their efforts. They may need to seek funding specifically for the initiative, which requires advanced planning and buy-in from higher levels of authority. If unsuccessful in increasing necessary resources, the initiative must be scaled down to what is achievable and of value with their given resources or abandoned altogether.

2. Gap Analysis

In order to determine whether an SE culture change initiative is appropriate, it is important to understand and document the current organizational culture as objectively as possible. This can prove difficult, as cultural aspects of the organization are highly perspective based and can be expected to vary between individuals. There may also be several cultures or subcultures present across organizational layers. This must be recognized by leadership when determining current state. Honest discussion and open communication across all organizational layers is a key parameter for culture change success. "[The] biggest cause of a failed change management initiative is a lack of communication and employee involvement at every level of the organization. Without involvement, there is no ownership. And if the only voices promoting a change initiative are senior executives, the process is bound to fail" (The Clearing 2017). When change initiatives are based on the perceptions of one organizational group, such as executive leadership, an incomplete understanding of the issues may lead to potentially unwise decisions. This potential area of bias through usage of faulty or incomplete data must be mitigated through the strategic involvement of key stakeholders from every organizational area when determining the current and desired culture states. The involvement of key operators or "boots on the ground" is particularly necessary to determining actual versus perceived state. The risk of gathering incomplete or incorrect information is further mitigated by the usage of change techniques during this phase.

Once the current state has been established, it can be compared to the desired state and gaps between current and desired state should be identified. Organizations have limited resources of labor and funding and the organization's ability to scope a culture change initiative may vary greatly depending on factors such as organizational size, structure and complexity. It is recommended that agencies prioritize their changes to achieve the most

benefit from their initiative. Doing so allows agencies to make short-term wins which create organizational momentum for the change initiative, as well as make the most of limited resources by addressing more urgent priorities first. Priorities may be determined by such factors as value or expected ROI (in the form of increased revenue or decreasing costs, achieving higher operational performance and meeting strategic and improvement goals), payback period and risk (Ho-Gland 2017). Gap analysis concludes the cultural discovery portion of the initiative. Once gap analysis results in identification of change requirements, subsequent requirements prioritization and recommendations for course of action, a culture change implementation plan is created. The implementation plan is the roadmap for the change initiative.

B. SYSTEMS ENGINEERING CULTURE IMPLEMENTATION PLAN

During the cultural transformation process, the implementation plan is created. The implementation plan consists of the necessary step-by-step actions which the organization must take to close the gap between current and desired state, founded on the cultural discovery phase findings and recommendations. These actions will vary by individual agency. However, there are common factors which most agencies will need to consider when creating their implementation plan. These include creating organizational visibility and incentivizing motivation for the culture change as outlined in Figure 3.

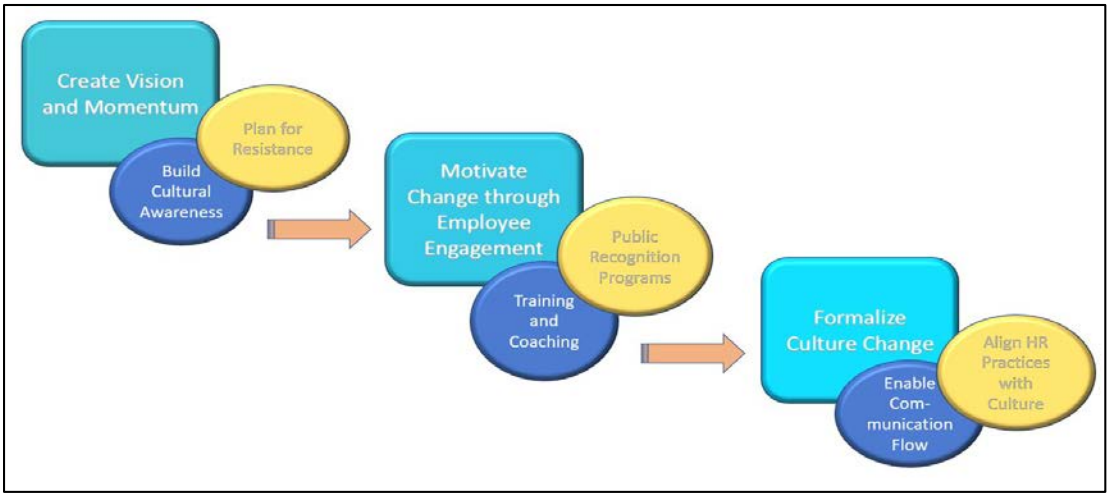

Figure 3. Systems Engineering Culture Implementation Plan Steps

1. Create Visibility and Momentum

Once priorities have been established, the agency must formulate an implementation plan for how to specifically achieve desired change. This takes place at leadership level with input from all layers of the organization. Of course, the agency will not be able to gather the perspectives and inputs from all of its employees directly, which is why it is necessary to identify change champions, or key personnel from across all layers of the organization to ensure the entire organization's perspective is represented and integrated as necessary into the change plans. This helps ensure that planning is grounded on accurate information. Change champions also help promulgate desired change throughout the organization, which is necessary for the culture change to take root and build momentum. If the change is not visibly supported throughout the organization, it is likely to fail. Creating a shared vision across the organization requires significant and sustained leadership and stakeholder effort. "[The] help of key stakeholders communicating the message repeatedly up, down and across the organization ensures the momentum and enthusiasm for change is not diminished over time. Communication by top management is seen as a powerful lever in gaining commitment and building consensus to required change" (Graetz 2000, 551). Leadership and stakeholders must show employees the value they themselves place on the change initiative through their own actions and through continued communication throughout employee ranks. Change initiatives which are issued as top-down directives with little follow-up are highly subject to failure, as there is no sustained visibility to the average employee and no employee buy-in has been generated. "One of the most important realities of organizational life is that top-down dictates don't greatly energize people on the 'front lines'…These individuals are rational and they know how to comply. Yet the key motivator for their performance is their day-to-day emotional commitment to the work that they do" (Etheredge and Beyers 2011, 56). Some organizations which are typically top-down directed, such as the military or federal agencies, will need to consciously address this aspect of change management, as their usual processes may not be in alignment with change management best practice models.

a. Build Culture Awareness

One way to build visibility and also create employee buy-in is by actively building culture change awareness within the average employee. During this phase, it is essential that leadership clearly articulate the changes being made, why they are being made and the value the changes are expected to bring to the agency. Otherwise, the average employee will have little incentive to participate in bringing change about and may even have little awareness of what is expected of them. Within federal agencies, communication can be accomplished through email, townhall style meetings, and informational flyers posted prominently in public spaces throughout the campaign. Townhall meetings which allow for questions to leadership are especially recommended throughout the change process, as they make visible leadership's commitment to the change. These meetings allow the average employee to participate in the change process by asking questions and raising their concerns. It is participatory in nature and may help employees feel more invested in the change because they had a say in the change process. It also provides a key information channel to leadership, so critical information can flow from the ground floor. This information flow provides leadership with a more complete perspective and awareness of the organization as a whole and may lead to corrections and updates to the implementation plan which otherwise would have to be addressed after deployment.

b. Plan for Resistance

Resistance to change within the organizational ranks should be expected, as it is a well-documented aspect of change initiatives. "In the context of change management research, the issue of resistance occupies a crucial place. Organizations should be aware of the human element and its implications for the success of all change management decisions…Managers who ignore this last element guarantee themselves an uphill battle, if not a sure failure" (Betah et al. 2013, 113). The workforce contains employees with diverse personality types and behaviors, which influence how each employee responds to different situations. Change is handled differently by each individual. It can be difficult for individuals to process and has a studied emotional component, which may be particularly visible when the requested changes affect the culture surrounding employees. "Organizational culture and structure change is inevitable due to the constant change in

technology, customer and markets, social and political pressures, as well as demographic characteristics. Resistance to change is an emotional and behavioral response by the affected employees to actual or imagined threats to an established work routine" (Brown n.d.). Resistance to change can be caused by fear of failure, status loss, discomfort operating outside of established social norms and routines, lack of visible reward system and/or lack of understanding or disagreement regarding need for change. However, overcoming resistance can be planned for and strategically countered by leadership through honest and direct communication, seeking employee input into the change process, and implementing strategies for employee motivation.

2. Motivate Change through Employee Engagement

Motivating employee participation in the culture change initiative is of paramount importance. "Motivated employees are needed in our rapidly changing workplaces…Motivated employees are more productive. To be effective, managers need to understand what motivates employees within the context of the roles they perform. Of all the functions a manager performs, motivating employees is arguably the most complex" (Lindner 1998). If leadership fails to provide sufficient incentive and motivation to employees make the requested changes, individual employees may decline to participate in the change initiative, causing the initiative to lose momentum and fail to achieve its goals. There are many theories of motivation, including Maslow's need-hierarchy theory, Herzberg's two-factor theory, Skinner's reinforcement theory, and Vroom's expectancy theory. These theories highlight different approaches to the issue of employee motivation. Motivation may be generated through positive and negative means. Negative means include giving employees poor performance evaluations which affect their pay structure or possibly letting employees go. Positive motivators include public recognition, financial rewards, job enrichment, training and learning opportunities, and job security. There are also intrinsic and extrinsic motivational factors. Due to HR regulations, federal agencies are much less likely to be able to rely on negative and extrinsic motivation factors to incentive employee buy in to the change (McPhie and Rose 2009, 29). However, they are able to capitalize on many intrinsic motivators and utilize extrinsic motivators to the best of their abilities. Intrinsic motivators within federal agencies include clear goal setting by

leadership, stressing the value of change to serving the mission and actively engaging employees in the change process. It is thought that many employed in federal agencies are interested in the service component of the organization and may be more likely to voluntarily engage with the change if they understand its value to the mission. Federal agencies may make use of extrinsic and intrinsic motivational factors aligned with learning opportunities and public recognition programs.

a. Training and Coaching

One of the primary factors for employee change resistance and lack of employee motivation to participate in the change is due to fear and insecurity (Quast 2012). The proposed changes may require employees to use unfamiliar processes and learn new skills. The agency must be prepared to incorporate significant employee training into the implementation plan to help employees feel comfortable and informed with their new roles and leadership expectations. Most federal agencies are given a training budget, which can be utilized to set up training workshops aligned with the initiative.

Change can also be incentivized by offering opportunities for employees to enhance their skillsets and resumes through formal certification and scholastic programs related to the SE culture change initiative. The agency may offer scholastic opportunities for motivated employees to receive college degrees or certifications related to SE. These programs need to be actively advertised to employees and visibly supported by leadership as a means by which agency employees can improve their career prospects.

b. Public Recognition Programs

Employees can also be intrinsically incentivized to participate in change through creation of public recognition programs. These programs can be implemented at minimal cost to the agency but can give large returns to the change initiative. Creating public recognition programs related to the SE culture change provides a forum for leadership to continually bring visibility to the importance placed on the culture change by publicly recognizing employees positively contributing to the SE initiative. These programs can give certificates of recognition, coins and other tokens as part of the program. The important part is providing these awards publicly and stressing their alignment with the

culture change. Any opportunities to provide public, positive feedback to participating employees should be explored. Very high performers may be given service awards or time off awards as allowable by HR practices, which again should be aligned to the SE culture change initiative.

3. Formalize Culture Change

At this point, leadership must take steps to institutionalize the culture change through formalization of policies, processes, systems and structures. "[It's] also important to realize that behavior and performance affect culture; culture is not only a causal factor, it's also a dependent variable affected by other critical execution-related factors. Incentives, structures, decision processes, behaviors, people, and controls affect and shape culture" (Wharton at Work 2011). This can be done through implementing policies and processes aligned with the desired culture (which should now be aligned with the organization's stated mission, vision and goals). Training, learning and incentive programs should be in place to promote and reinforce desired behaviors. By formalizing and actively supporting the desired culture, it becomes the framework intrinsically guiding employees through their daily activities with less direct oversight required from managers and leadership. Once the change initiative has been fully implemented and standardized into the workplace, it is important for leadership to continue to bring visibility to the desired culture, and to monitor and measure its success in attaining goals. Adjustments should be made as necessary.

a. Enable Communication Flow

One of the key attributes of an SE culture is enabling effective channels of communication between organizational layers. The bureaucratic, vertical structure of federal government generally favors a top-down or autocratic communication process, which is "the process of upper management or the chief executive officer reaching independent conclusions that change or improve the workplace or business systems…. These conclusions are then handed down to employees, who work to accomplish the goals on their own or with other employees" (Harper 2015). Top-down communication and directives are to be expected within the federal agency environment and agency culture

change initiatives must account for this. However, an SE culture requires engagement and effective communication between leadership and all organizational layers. Communication processes designed to facilitate information flow within the hierarchy must be created and then actively supported by leadership; this can be difficult to achieve within any large organization and may require a significant cultural shift for federal agency leadership used to operating in a strictly top-down communication environment. One possible way to break through organizational hierarchies is by implementing and emphasizing the organization-wide utilization of communication and collaboration platforms, such as those offered by private industry IT company, Slack, available DoD communication tools such as Defense Collaboration Services and wikis. These types of communication tools provide organizations with the means to increase speed of communication, break through hierarchies by opening communication channels, and increase information availability by preventing the creation of information silos. They do so by "[creating] areas of experimentation and innovation in which employees may try out and develop solutions. This enables and promotes communication, collaboration and networking…. Structures become more agile, knowledge silos are reduced and employees are strengthened in their self-management. This ultimately leads to a cultural change" (Tandemploy 2018). Just as important as timely and effective information flow is receptivity. Receiving information is not useful if it is not openly considered. Leadership must provide an environment that allows for information flow and actively promote leadership consideration of the provided information, regardless of whether the information is ultimately acted upon.

b. Align Human Resource Practices with Culture

As part of the formalization process for the culture change, federal agencies should consider highlighting their culture when conducting HR actions such as recruitment, retention, career development and career path modeling. At this point in the culture change process, organizations should have their SE culture aligned with their specific mission, vision and goals, and recruitment outreach and retention policies should emphasize these with potential and current employees. With recruitment, the intent is for hiring and outreach materials to resonate with like-minded potential employees, who will subsequently seek employment and embrace the prevailing organizational culture when hired. For all HR

actions, agencies should find ways to bake in the preferred culture to the hiring practices by aligning desired knowledge, skillsets and abilities with the new culture as much as possible. This allows agencies to formally integrate SE supportive requirements at the human resource level and provides a lever with which to require and evaluate employees' performance in the position's SE element.

Federal agencies now have available a verified Systems Engineering Career Competency Model (SECCM) to strategically manage their workforce to align with an SE culture. The model is available to hiring managers through Selection Manager, a HR system administered by USA Staffing (USA Staffing n.d.), for the development of job announcements in USAJOBS (USAJOBS, n.d.). The SECCM identified 44 SE core competencies and 179 SE tasks (Whitcomb et al. 2017, 19), which can be applied to position descriptions and job announcements (even non-engineer) as needed to align positions to support an SE culture. "The verified SECCM competencies and tasks can be used for 'high stakes' HR functions like creating (and maintaining) position descriptions, creating job announcements, assessing job candidates, hiring, and providing a basis for employee performance assessments and ratings" (Whitcomb et al. 2017, 16). Competencies and tasks are individually selected as applicable, though it is recommended that enough items are included to support measurable employee performance in the SE element. The 44 SE core competencies are broken down into four distinct categories: technical management, business acumen, analytical, and professional. It is non-series specific and can be applied at grade-levels 07–15. See Table 2.

Table 2. SECCM Competencies Organized by DAU Engineering Categories. Source: Whitcomb et al. (2017).

SYSTEMS ENGINEERING CAREER COMPETENCY MODEL			
Technical Management	**Business Acumen**	**Analytical**	**Professional**
Acquisition	Industry Awareness	Transition	Communication
Risk Management	Organization	Integration	Leading High-Performance Teams
Requirements Management	Cost Estimating	Design Considerations	Personal Effectiveness/Peer Interaction
Configuration Management	Proposal Process	Tools and Techniques	Problem Solving
Technical Assessment	Supplier Management	Stakeholder Requirements Definition	Professional Ethics
Data Management	Negotiations	Validation	Strategic Thinking
Software Engineering Management	Cost, Pricing and Rates/Cost Management	Verification	Coaching and Mentoring
Decision Analysis	Financial Reporting and Metrics	Mission-Level Assessment	Managing Stakeholders
Interface Management	Business Strategy	Architecture Design	Mission and Results Focus
Technical Planning	Industry Motivation, Incentives, Rewards	Implementation	Sound Judgment
	Contract Negotiations	Engineering Disciplines	Continual Learning
		Requirements Analysis	

C. LEADERSHIP AND STAKEHOLDER CONSIDERATIONS

Leadership and key stakeholders hold special roles in culture change initiatives. Leadership is responsible for generating the strategic vision that is central to the proposed changes. “The leader’s job is to create the vision for the enterprise in a way that will engage both the imagination and the energies of its people.…The vision must be tied to what the firm values, and the leader must make this connection in a way that the organization can understand, grasp, and support” (Fuller and Green 2005). Leadership is responsible for setting the goals for the organization and providing employees with a clear path to attaining

those goals. Mandating change without clarifying why the change is needed, without publicly supporting the change or providing a means to achieving change is unlikely to lead the way to successful change implementation, and federal leadership must be careful to avoid this scenario. Without sustained leadership engagement, the culture change will likely fail as the initiative loses visibility and momentum and the average employee senses the lack of leadership commitment to the change. Leadership plays a critical role in change initiatives in any organization but is particularly critical for public organizations, since they are severely constrained in the extrinsic motivators they can offer. Public leadership must rely on intrinsic motivational factors, and much of what federal agencies can offer by way of intrinsic motivators lies directly in leadership's hands. Leadership must achieve employee participation and employee buy-in to the change, and they can do so through active engagement. It is leadership's role to clearly communicate why change is needed, the form the changes will take and the impact that average employees can expect. According to research, more than 50% of organizations "fail in this first phase [of change]. What are the reasons for that failure? Sometimes executives underestimate how hard it can be to drive people out of their comfort zones. Sometimes they grossly overestimate how successful they have already been in increasing urgency. Sometimes they lack patience" (Kotter 1995). It is leadership's role to continually follow up and ensure the change initiative is being communicated across the agency and is well understood. Though they are not responsible for managing their implementation, leadership is responsible for crafting solutions to foster culture change initiative success, such as training programs, public recognition programs and providing SE tools.

Key stakeholders also play a prime role in the culture change process. Without participation and enthusiasm for change from key stakeholders, it is very difficult to get an informed perspective of the entire organization and equally difficult to ensure the change message is disseminated and active participation generated throughout. These key stakeholders or guiding coalition are necessary to counter resisters and propagate change efforts. Without a strong coalition for change, the organization "can make apparent progress for a while. But, sooner or later, the opposition gathers itself together and stops the change. In every successful transformation effort…the guiding coalition develops a

picture of the future that is relatively easy to communicate and appeals to customers, stockholders, and employees" (Kotter 1995). It can be difficult to identify good candidates for the coalition, particularly at the non-executive levels of the organization. Due to resourcing issues, there may be a tendency to select coalition members simply because those employees have fewer responsibilities and will not be missed on other projects. However, that is short sighted and self-defeating. If there is truly an executive level commitment to change, then the change initiative must be prioritized and resourced as appropriately as possible. On the other hand, particularly in cases of culture change, good coalition members are not necessarily the best technical performers. They should be key individuals across all organizational layers who are well-networked, well-respected and influential in the organization. Winning them over to the culture change and making them change champions can go a long way in engaging the entire organization with the initiative.

D. THE ROLE OF RISK MANAGEMENT

As with any strategic change, risk management should be integrated into the culture change process. Risks should be systematically anticipated, considered and addressed throughout the strategic planning and implementation process, using a risk management framework. Utilizing key stakeholders across organizational layers also helps with risk mitigation, as it allows for the complete perspective of the organization to be represented, which in turn empowers better, more informed decision making. "There can be a variety of risks that undermine change initiatives. Generally these issues deal with three underlying drivers of execution risk: availability of critical resources, stakeholder commitment and alignment, and emotional and social resistance" (Kambil 2017). Another way risk can be managed is by formulating a governance structure and process for the change. This may be particularly helpful for federal agencies to address their resourcing constraints and ensure stakeholder commitment, as it may aid agencies in raising accountability and formalizing roles and responsibilities for the change effort.

Culture change initiatives have a large emotional and social component that needs to be recognized and accounted for. If not adequately addressed, resistance and apathy can overcome the initiative. "Addressing emotional and social risks requires some level of

anticipating the likely habits, fears, power, social satisfaction, and cultural beliefs that drive resistance to change. Once these risks have been anticipated, they can be addressed through thoughtful communications, the redesign of work, and actions to assuage fears and concerns" (Kambil 2017). These types of risk are somewhat subjective, and it can be difficult to anticipate the exact ways they may manifest during the change process. However, change research consistently shows that resistance to change and other emotion-based responses to the proposed change initiative is to be expected and must be strategically mitigated. As the change initiative progresses, feedback mechanisms should be in place to determine the status of the change. Risk identification and mitigation strategies should be updated in real-time to address new and changing risks.

E. CHAPTER SUMMARY

Moving forward with a culture change initiative requires advanced planning and a carefully constructed implementation plan crafted specifically to address the unique agency environment. In order to successfully curate an SE culture, the agency may make use of intrinsic and extrinsic motivational recommendations within an agency-based culture change framework. Leadership plays a critical role in underwriting culture change. Without full leadership engagement and active participation, the initiative is subject to high risk of failure. Risk management activities must also be conducted to maximize culture change probability of success.

V. CONCLUSIONS

Today's federal agencies are consistently tasked to improve their efficiency and effectiveness, by accomplishing more to support the taxpayer while using fewer resources. Using SE methods consistently within federal agencies may support such efficiency gains. Literature review supports the benefits of applied SE, particularly for those organizations with complex products and systems and enterprise-level organizations. Benefits were not limited to technical and engineering type organizations. Systems engineering is at heart a critical thinking methodology which can be applied to enterprise-level problem solving, as well as to individual projects involving systems and product development. Systems engineering has a maturity component and can be implemented at various maturity levels, which may enable more organizations to derive benefits from SE at the level of usage appropriate for their individual circumstances.

A. FINDINGS AND RECOMMENDATIONS

Performance, schedule and cost performance gains were all reported for projects utilizing SE methods when compared to non-SE projects of similar complexity. Life cycle costs were decreased by 10–20%. However, these benefits were only found in cases where adequate resourcing was given to the SE project. ROI was tightly aligned with the complexity level of applicable organizations and programs; greater complexity equated to higher ROI. Resources included incorporating scheduled time for SE activities, appropriate personnel resources and budget. The three case studies presented demonstrate that 10–15% of total project cost should be dedicated to supporting SE activities, in order to receive optimal benefit from SE. Furthermore, SE needs to be applied correctly and consistently for benefits to be attained. This indicates that a supportive SE organizational culture is a requirement for successful SE application within agencies. Culture change initiatives come with their own costs and have high rates of failure if not carefully managed. Federal agencies must conduct a cost-benefit analysis to determine if an SE culture, with its implementation and sustainment level costs, is worth the investment.

Culture change initiatives are difficult and are best managed by utilizing a culture change management framework for strategic and implementation planning. However, not all frameworks address the unique constraints under which federal agencies operate. Many traditional culture change frameworks rely heavily on extrinsic motivators, which are often financially-based. Public motivation theory relies heavily on intrinsic, non-financial motivators which are available to federal agencies. Intrinsic motivators require high levels of time and commitment from leadership and stakeholders to be of benefit. Of key importance is achieving change buy-in from the average employee, which may be managed through clear goals setting and continued communication, linking the change with its value to the service mission, actively soliciting employee participation in the initiative, providing training and other learning opportunities, and providing forums for public recognition and positive feedback aligned with the initiative.

Changing to an SE culture requires dedicated and sustained support from leadership and key stakeholders and significant resourcing of time, money and personnel. Should honest analysis show that consistent support for the initiative cannot or is unlikely to be provided, it is best not to proceed with the culture change as full support is needed for the initiative to succeed. Agency leadership may need to seek approvals and additional funding from higher authorities to proceed with such an initiative. This may be difficult to secure, as much of the benefits of SE are hard to quantify, but the costs of applying SE are quite visible. As federal agencies come under tighter budgetary restrictions, justifying what is likely to be viewed as an overhead or special project cost requires excellent support reasoning built on value analysis. Systems engineering is well known in private industry and some federal agencies, but it is likely that some marketing and education regarding the value of SE may need to be done by the soliciting agency to receive approval from higher authorities. There are many directives, regulations and recommendations related to SE usage within the federal government and particularly the DoD, which should be researched and included as part of the approval request to strengthen the soliciting agency's position. The common usage of SE within private industry and its value application to the government acquisition of outside products and services should also be used to justify the initiative.

B. AREAS FOR FURTHER STUDY

This study conducts a high-level value analysis for application of SE within organizations of varying type and highlights the requirement for a supportive SE culture in order for optimal value to be achieved. Organizational culture change and associated public agency constraints were discussed and strategic and implementation recommendations for a federal agency SE culture change initiative outlined. Recommended areas of future study include conducting analysis based on specific federal agency department type (such as the DoD or Department of Energy) and conducting a case study for SE culture implementation at the agency level using the recommendations included in this paper.

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