NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

SYSTEMS ENGINEERING CAPSTONE PROJECT REPORT

SYSTEM ENGINEERING HEALTH AND VISUALIZATION

by

SSC LANT Vikings Team
Cohort 311-132W

December 2014

Project Advisors: Rama Gehris
Bonnie Young

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704–0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.

1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** December 2014	**3. REPORT TYPE AND DATES COVERED** Capstone Project Report
4. TITLE AND SUBTITLE SYSTEM ENGINEERING HEALTH AND VISUALIZATION		**5. FUNDING NUMBERS**
6. AUTHOR(S) Cohort 311-132W/SSC LANT Vikings Team		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000		**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A		**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.		
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited		**12b. DISTRIBUTION CODE** A

13. ABSTRACT (maximum 200 words)

Complex warfighter systems are increasingly required for continuing United States dominance, which drives a need for high quality Systems Engineering (SE) processes. A System Engineering Health and Visualization (SEHV) capability is needed so that leadership can gain insight into potential SE risk areas, allowing them to be proactive instead of reactive to issues leading to program failures, thus saving time, effort, and costs. This capstone's purpose was to determine if an automated means of collecting and displaying SE data trends is feasible and effective.

To accomplish this, the team analyzed stakeholder's requirements and performed a literature study on SE leading indicators. Modeling and simulation was performed to further analyze these requirements and provide the best means to obtain SE health data from Space and Naval Warfare System Center Atlantic (SSC-A). This developed the SEHV architecture to include data integration strategy. A conceptual model for the SEHV capability was produced along with acquisition strategies and cost estimates.

The research shows a need to incorporate an automated SEHV system into SSC-A's organization to improve efficiencies in data calls and management insight into the SE health of a program. Additionally, the team identified future research requirements and provided recommendations for management consideration.

14. SUBJECT TERMS visualization, trends, risks, system engineering leading indicators			**15. NUMBER OF PAGES** 239
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540–01-280-5500

Standard Form 298 (Rev. 2–89)
Prescribed by ANSI Std. 239–18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

SYSTEM ENGINEERING HEALTH AND VISUALIZATION

Cohort 311-132W/SSC LANT Vikings Team

Chester Alonzo (MSES) Michael Besco (MSSE) Theresa Inman (MSES)

Michael Jourdain (MSSE) Regina McNeil (MSES) Clive Sugama (MSSE)

Submitted in partial fulfillment of the
requirements for the degrees of

MASTER OF SCIENCE IN SYSTEMS ENGINEERING
AND
MASTER OF SCIENCE IN ENGINEERING SYSTEMS

from the

NAVAL POSTGRADUATE SCHOOL
December 2014

Lead editor: Regina McNeil

Reviewed by:
Rama Gehris
Project Advisor

Bonnie Young
Project Advisor

Accepted by:
Cliff Whitcomb
Systems Engineering Department

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Complex warfighter systems are increasingly required for continuing United States dominance, which drives a need for high quality Systems Engineering (SE) processes. A System Engineering Health and Visualization (SEHV) capability is needed so that leadership can gain insight into potential SE risk areas, allowing them to be proactive instead of reactive to issues leading to program failures, thus saving time, effort, and costs. This capstone's purpose was to determine if an automated means of collecting and displaying SE data trends is feasible and effective.

To accomplish this, the team analyzed stakeholder's requirements and performed a literature study on SE leading indicators. Modeling and simulation was performed to further analyze these requirements and provide the best means to obtain SE health data from Space and Naval Warfare System Center Atlantic (SSC-A). This developed the SEHV architecture to include data integration strategy. A conceptual model for the SEHV capability was produced along with acquisition strategies and cost estimates.

The research shows a need to incorporate an automated SEHV system into SSC-A's organization to improve efficiencies in data calls and management insight into the SE health of a program. Additionally, the team identified future research requirements and provided recommendations for management consideration.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I. INTRODUCTION 1
- **A. PROJECT OVERVIEW 1**
  - **1. Problem Statement 1**
  - **2. SSC-A's Current State 1**
- **B. BACKGROUND 3**
  - **1. Project Background 3**
  - **2. Literature Review 6**
  - **3. Team Organization 7**
  - **4. SSC-A Active Stakeholders 10**
  - **5. Project Objectives 10**
  - **6. Research Questions 12**
- **C. APPROACH 14**
  - **1. SEHV Project Approach 14**
  - **2. SEHV SE Approach 16**
  - **3. SEHV SE Process 17**
    - ***a. Problem Definition/Needs Analysis 20***
    - ***b. Requirements Analysis/Metrics Analysis 21***
    - ***c. Functional Analysis 21***
    - ***d. System Architectural Modeling 22***
    - ***e. System Analysis 22***
  - **4. Risk Management 23**

II. REQUIREMENTS ANALYSIS 25
- **A. REQUIREMENTS ELICITATION 25**
  - **1. Stakeholder Requirements 25**
  - **2. SEHV Decomposed Requirements 26**
- **B. FUNCTIONAL ANALYSIS 30**
- **C. SELECTION OF LEADING INDICATORS 32**
  - **1. SELI Down Select Process 33**
  - **2. Current External Tool Sources 34**
  - **3. Stakeholder Roles and Descriptions 35**

III. SEHV ACQUISITION OPTIONS ANALYSIS AND SELECTION 37
- **A. ARCHITECTURE OPTIONS 37**
  - **1. Manual Method 37**
  - **2. Automated Method 38**
- **B. ACQUISITION OPTIONS 38**
  - **1. Automated Independent COTS Tools (All COTS) 39**
  - **2. Automated Centralized GOTS System 40**
  - **3. Automated Hybrid Solution Set 41**
- **C. ANALYTIC HIERARCHY PROCESS (AHP) EVALUATION CRITERIA 42**
  - **1. Assumptions 42**

2. Constraints....43
3. Safety and Security Certifications....44
D. ANALYTIC HIERARCHY PROCESS....46
1. Overview....47
2. Alternatives Comparison....48
3. Conclusion to Solution Strategy....55

IV. SELECTED SELI DETAILS....59
A. SELI 9, RISK EXPOSURE TRENDS....59
1. Associated Process....60
2. Data Collection Procedure....60
3. Data Storage....61
4. Data Analysis Procedure....63
5. Historical Data....64
6. Sample Visualizations....64
B. SELI 11 , SE STAFFING AND SKILLS TRENDS....65
1. Associated Process....70
2. Data Collection Procedure....70
3. Data Storage....71
4. Data Analysis Procedure....72
5. Historical Data....73
6. Sample Visualizations....74
C. SELI 12 PROCESS COMPLIANCE TRENDS....75
1. Associated Process....79
2. Data Collection Procedure....82
3. Data Storage....83
4. Data Analysis Procedure....84
5. Historical Data....85
6. Sample Visualizations....85
D. SELI 13, TECHNICAL MEASUREMENT TRENDS....86
1. Associated Process....88
2. Data Collection Procedure....88
3. Data Storage....92
4. Data Analysis Procedure....93
5. Historical Data....94
6. Sample Visualizations....94
E. SELI 16 SYSTEM AFFORDABILITY TRENDS....95
1. Associated Process....97
2. Data Collection Procedure....99
3. Data Storage....100
4. Data Analysis Procedure....102
5. Historical Data....103
6. Sample Visualizations....103

V. MODELING AND SIMULATION....105
A. MANUAL MODEL....105
B. GENERIC SEHV MODEL....107

C. MANUAL VERSUS SEHV COMPARISONS 108
1. Manual Simulation 108
2. SEHV Simulation Results 111
3. Experiments 114
4. Conclusion 117

VI. SYSTEM ANALYSIS 119
A. COST ANALYSIS 119
1. Manual Method Costs 120
2. Automated Hybrid Solution Costs 121
B. PERFORMANCE 123
C. POTENTIAL SYSTEM RISKS 124

VII. CONCLUSIONS AND RECOMMENDATIONS 129
A. CONCLUSIONS 129
B. RECOMMENDATIONS 130
C. PROPOSED AREA OF FUTURE STUDIES 130

APPENDIX A. RISK SUPPORT 133
A. APPLICATION RISKS 133
B. SUGGESTED METHODS OF RESOLVING RISKS 133
C. MITIGATION EFFORTS FOR CAPSTONE PROJECT RISKS 134

APPENDIX B. SEHV PROJECT MANAGEMENT PLAN 139

APPENDIX C. SSC-A'S CAO CONOPS AND IPT HANDBOOK STAKEHOLDER CHARACTERIZATION WRT SELIS 175

APPENDIX D. RESEARCH QUESTIONS AND ANSWERS 197
1. Data Sources 197
2. Data Collection 198
3. Data Storage 198
4. Data Analysis 200
5. Data Display 200
6. SEHV Stakeholders 200
7. SELIs 201
8. Other Topics 201

APPENDIX E. SUPPLEMENTALS 203

LIST OF REFERENCES 205

INITIAL DISTRIBUTION LIST 211

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

Figure 1. SSC-A's SEHV Current State 2
Figure 2. SEHV Capstone Organizational Structure 8
Figure 3. OV-4 SSC-A Active Stakeholders 10
Figure 4. SEHV Capability Context Diagram 11
Figure 5. SEHV Capability OV-1 12
Figure 6. SEHV Project Approach 16
Figure 7. SEHV SE Process Diagram 19
Figure 8. SEHV High Level Project Plan 20
Figure 9. Most Valued SELI Based on SSC-A CAO CONOPS and IPT Handbook 34
Figure 10. SEHV Analytic Hierarchical Process Diagram (after Green 2013) 48
Figure 11. Pairwise Comparison Matrix (from Green 2013) 49
Figure 12. Criteria Comparison (after Green 2013) 50
Figure 13. Alternatives with Respect to Data Collection (after Green 2013) 51
Figure 14. Alternatives with Respect to Capture and Analyze Required Data Elements (after Green 2013) 52
Figure 15. Alternatives with Respect to Cost Effectiveness (after Green 2013) 53
Figure 16. Alternatives with Respect to Data Storage (after Green 2013) 54
Figure 17. Alternatives with Respect to Data Trends Display (after Green 2013) 55
Figure 18. Criteria versus Goal Comparison (after Green 2013) 56
Figure 19. Priority Relationship Calculation Matrix (after Green 2013) 57
Figure 20. Criterion Priority with Respect to Acquisition Option (after Green 2013) 57
Figure 21. Risk Exposure Trends (from INCOSE et al. 2010) 64
Figure 22. Planned SE Effort versus Actual SE Effort 67
Figure 23. SE Staff and Skill Trends (from INCOSE et al. 2010) 74
Figure 24. SSC-A Joint Framework (from SPAWAR Atlantic 2014) 76
Figure 25. Process Management Procedure Diagram (from SPAWAR Atlantic CPI ESG 2014) 77
Figure 26. Process Compliance Procedure Diagram (from SPAWAR Atlantic CPI ESG 2014) 78
Figure 27. SE Process Compliance Discrepancy Trends (from INCOSE et al. 2010) 80
Figure 28. SE Process Compliance Discrepancy Diagram 81
Figure 29. Example Technical Planning Process Compliance Trends 86
Figure 30. Technical Measurement Elements (from Roedler and Jones 2005) 87
Figure 31. Technical Measurement Process (from Roedler and Jones 2005) 88
Figure 32. Technical Performance Index (from Roedler 2005) 95
Figure 33. Project Performance measured in terms of Affordability (from INCOSE et al. 2010) 97
Figure 34. Affordability Calculation (from INCOSE 2010) 98
Figure 35. Affordability Cost / Confidence Trends (from INCOSE et al. 2010) 104
Figure 36. ExtendSim Manual Data Call Process Model 106
Figure 37. ExtendSim SEHV Process Model 108
Figure 38. ExtendSim Manual Data Call Staleness 109

Figure 39. Manual Process Times 110
Figure 40. Manual Process Distribution in Days 111
Figure 41. ExtendSim SEHV Process Staleness 112
Figure 42. SEHV Process Times 113
Figure 43. SEHV Process Distribution in Minutes 114
Figure 44. Simulation Frequency Experiment 1 and 2.....116
Figure 45. Simulation Frequency Experiment 3 and 4.....117
Figure 46. Manual Method Costs Details.....122
Figure 47. Automated Hybrid COTS Tools with Central Database Costs Details 123

LIST OF TABLES

Table 1. SEHV Capstone Project Team Roles and Responsibilities 9
Table 2. SELI Trends 15
Table 3. Additional Risk Management Tools 60
Table 4. Risk Exposure Data Collection Procedure.....61
Table 5. Risk Data Elements.....62
Table 6. Risk Exposure Data Analysis Procedure 63
Table 7. SE Staffing and Skills Data Collection Procedure.....70
Table 8. Staffing and Skills Data Elements 71
Table 9. SE Staffing and Skill Data Analysis Procedure.....73
Table 10. Process Compliance Data Collection Procedure.....82
Table 11. Process Compliance Data Elements.....83
Table 12. Process Compliance Data Analysis Procedure 84
Table 13. Technical Measurement Data Collection Procedure.....89
Table 14. Technical Measurements Data Elements 93
Table 15. Technical Performance Data Analysis Procedure.....94
Table 16. System Affordability Data Collection Procedure 99
Table 17. System Affordability Data Elements 100
Table 18. System Affordability Data Analysis Procedure.....103
Table 19. Risk Table 127
Table 20. Risk Management Roles and Responsibilities.....133
Table 21. Program Risk Ranking.....134
Table 22. Additional Risks.....137

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

A&E	assignment and experience
AC	actual cost
ACAT	acquisition category
AF ESC	Air Force Electronic Systems Center
AHP	analytic hierarchy process
ALI	applied leading indicators
AOR	area of responsibility
BFM	business finance manager
BRAC	base realignment and closure
BP	business portfolio
BPB	business portfolio board
BSME	business subject matter expert
C&A	certification and accreditation
CAO	competency aligned organization
CB	competency board
CCB	configuration control board
CCTA	Central Computer and Telecommunications Agency
CDAD	cpars draft approval document
CDM	competency development model
CIMS	career information management system
CL	competency lead
CM	competency manager
CM	configuration management
CMGR	configuration manager
CMMI	capability maturity model integration
CMoI	competency member of integrated product team
CMPRO	configuration management professional
CO	commanding officer
COBRA	Consolidated Omnibus Budget Reconciliation Act
COG	command operating guide

CONOPS	concept of operations
COR	contracting officer representative
CORA	cost of risk analysis
COTS	commercial off the shelf
CPAR	contractor performance assessment reporting
CPI	continuous process improvement
CPIMS	civilian personnel information management system
CRAMM	ccta risk analysis and management method
CRG	cor resource guide
CRM	customer relationship model
CS	competency supervisor
CSCI	Computer Systems Center Incorporated
DCO	defense connect online
DC/ESE	data center / enterprise services environment
DCPDS	Defense Civilian Personnel Data System
DIMHRS	Defense Information Management Human Resource System
DITSCAP	defense information technology security certification and accreditation process
DOD	Department of Defense
DODAF	Department of Defense architecture framework
DON	Department of Navy
DOORS	Dynamic Object Oriented Requirements System
DPM	deputy portfolio manager
ECMF	enterprise cost management framework
ED	executive director
ERD	entity-relationship diagram
ERP	enterprise resource planning
ESC	executive steering council
ESG	executive steering group
EV	earned value
FFBD	functional flow block diagram

GOTS	government off the shelf
GWBS	global work breakdown structure
HIPAA	Health Insurance Portability and Accountability Act
HSI	human system integration
IEEE	Institute of Electrical and Electronics Engineers
INCOSE	International Council on Systems Engineering
IPR	in-progress review
IPT	integrated product team
ISEA	in-service engineering agent
ISO	International Organization for Standardization
IT	information technology
JF	joint framework
JIRA	not an acronym
KSA	knowledge, skill and ability
LCL	local competency lead
LSE	lead system engineer
MBSE	model based system engineering
MGMT	management
MOE	measures of effectiveness
MOP	measures of performance
MOU	memorandum of understanding
MS	Microsoft
MSES	Master of Science in Engineering Systems
MSSE	Master of Science in Systems Engineering
MVI	master veteran index
NAVAIR	Naval Air Systems Command
NAVFAC	Naval Facilities Command
NCL	national competency lead
NERP	Navy Enterprise Resource Planning
NIACAP	national information assurance certification and accreditation process

NIST SP	National Institute of Standards and Technology Special Publications
NOLA	New Orleans Louisiana
NPS	Naval Postgraduate School
NSIPS	Navy Standard Integrated Performance System
NWA	network activity
OBS	organizational breakdown structure
ODC	other direct cost
OIG	office of inspector general
OM	operations maintenance
OMN	operations maintenance Navy
OP	operations procurement
OPN	other procurement Navy
OV	operational view
P2MC	project planning monitoring and control
PLC	project life cycle
PM	project manager
PMP	project management plan
POA&M	plan of actions and milestones
POP	period of performance
PSE	program support engineer
PSM	Practical Software and Systems Measurement
PV	planned value
QA	quality assurance
QM	quality management
RDT&E	research, development, test and evaluation
REQM	requirements management
RM	risk management
RML	risk management log
RMT	risk management team
RO	risk owner
ROM	rough order of magnitude

S&T	science and technology
SA	system administrator
SAM	support agreements manager
SCN	shipbuilding and conversion Navy
SAnDS	strategic analysis and decision support
SE	systems engineering
SEHV	System Engineering Health and Visualization
SELI	system engineering leading indicator
SEMP	system engineering management plan
SEP	system engineering plan
SETR	system engineering technical review
SME	subject matter expert
SOM	strategic operations manager
SP	share point
SP	sub portfolio
SPAWAR	Space and Naval Warfare Systems Command
SPAWARSYSCOM	SPAWAR Systems Command
SPAWARSYSCENLANT	Spawar Systems Center Atlantic
SSC-A	Space and Naval Warfare Systems Center Atlantic
SSC-PAC	Space and Naval Warfare Systems Center Pacific
SSS	support services specialist
SWOT	strengths, weaknesses, opportunities and threats
TAA	team assignment agreement
TELCOM	telephone communication
TFFMPS	Total Force and Fleet Manpower System
TO	technical order
TPM	technical performance measure
TPO	thesis processing office
TWMS	Total Workforce Management System
VA	Veteran Affairs
VBMS	Veteran Benefits Management System
V&V	verification and validation

WBS	work breakdown structure
WRT	with respect to
XML	extendible markup language
XO	executive officer

EXECUTIVE SUMMARY

Project risk can result in cost overruns, schedule slippage, and performance degradation. The capability to assess the current health of a project within a large organization can help predict and reduce project failure. A literature survey pointed to INCOSE's System Engineering Leading Indicator (SELI) Guide v2, which provides methods to expose a project's current and potential future states. Displaying trends to reveal leading indicators can help facilitate leadership's necessary actions from leadership to assist a project to get on the track for success. This guide emphasizes eighteen SELIs that can help leadership identify project risk and to intervene in a situation where a project is struggling. All of these SELIs are important; however the scope of this Capstone project required selecting a few appropriate SELIs to implement for effective intervention.

Data elements from projects need to be gathered to produce SELI trends. SSC-A currently executes numerous manual data calls to obtain information about projects. Coordination and continuous monitoring is involved with the manual data call process. Leadership has to decide on how to collect the data, who are the key personnel to obtain the information, what information is needed, where can the progress of data calls be viewed (e.g., share drive, command website, email, or during scheduled meetings), when should the data call deadline be, and why the data call is even needed. Skill sets and availability of personnel requested to respond to data calls may be inconsistent with the type of data desired and the frequency of requesting this information. These types of data calls disturb SE / SE management from their daily tasks. Inaccurate information delivered from SE / SE management can produce unfavorable results such as data not being received by leadership in a timely manner due to repeated errors, which require rework.

To display SELI trends the current manual data call system and three procurement options that could be used to implement the SEHV system were considered. The procurement options were automated independent Commercial Off The Shelf (COTS) solution, automated centralized GOTS system, or an automated hybrid solution set. Analyzing the pros and cons with weighted criteria such as data collection, capture

and analyze required data elements, cost, data storage, and displaying data trends assisted with developing a AHP to determine the best solution. The hybrid solution set that involved a combination of an in-house developed database / graphic user interface and integration of SE tools / applications was the best solution for SEHV. Using these tools along with automating manual information gathering processes can support SELI visualization needs regarding a project's success.

Automating manual data call processes would help alleviate disturbing personnel, promote data collection consistency, and allow leadership to receive project information on a regular basis. To get the most out of data analysis for the decision-maker, visualization is needed. The VBMS project at SSC-A proves this concept by having visual depictions of technical data. Leveraging this capability along with SSC-A's Data Center / Enterprise Services Environment can support capturing, storing, analyzing, and displaying project health trends.

Modern SE software tools can produce necessary data elements for SELIs that aid the visualization of project trends. There are SE / SE management software and applications at SSC-A that are used throughout the command; however, enforcing other software that can augment SSC-A's current SE tool box would be required for applying SELI methodology. An automated process would include specific data elements being captured from these SE / SE management tools, stored to assist historical trend values, and analyzed by performing basic computations on the data to produce trending displays. These displays can show clear deviations of planned vs. actual values. These deviations could indicate risk on a project and even show if it is a repetitive occurrence.

Simulations replicate real-life scenarios within a virtual environment that assist improvement efforts. Manual data calls were simulated on the software ExtendSim to demonstrate how inefficient the current process really was. A sequential process, which started from leadership all the way down to the lower levels of the workforce and back, confirmed a time consuming set of manual tasks. The SEHV approach reduces some of these manual tasks by automating activities, and creating a faster / more efficient process. The SEHV methodology was also simulated to indicate that the manual process produced outdated "stale" data received by leadership. This stale data would be months

old, which at times prove useless. The SEHV system would include SE / SE Management personnel entering data in a common set of SE software tools and applications. These tools would provide data elements needed for SELI trends to a storage repository. An analytical function would take that stored data and compute simple arithmetic to produce arrays of numbers to fuel SELI trends over time. Parallel to SE / SE management personnel entering data into SE tools, leadership would log into the SEHV system to display project trends at their own convenience. Experiments were designed to determine the optimal frequency of SE software tool usage. To keep SELI trends fresh and up to date, using SE tools as specified in the SEHV process would be necessary.

Functional architectures for the SEHV system were depicted using SPEC Innovations Innoslate to produce IDEF0 standard functional models. This model displayed functions that were decomposed into lower levels. Providing SEHV, performing SE processes, providing SE tool functions, maintaining SEHV, and hosting SEHV were the high level activities of the IDEF0 architecture. This IDEF0 illustrates each entity's relationship with one another via the connected data elements.

An initial investment in the SEHV system at SSC-A would benefit the command by reducing excessive data calls relating to SE / SE management, saving money on man-hours spent during the manual data call process, providing the capability of displaying SELI trends, and the resultant ability to see and react to potential project risk. Methodology and recommendations within this capstone project lay the foundation for the SEHV capability. This capability automates traditional manual data call processes by utilizing technology that is available today to save taxpayer dollars along with providing a quality product to the warfighter.

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

The SSC-A Vikings would like to thank the members of the team, the advisors, professors Dr. Rama Gehris and Bonnie Young, NPS faculty and staff, our SSC-A leadership and stakeholders, and our families and friends for the countless hours of dedication and care provided while we completed this journey. The team realizes and appreciates the sacrifice made for us while we completed this pursuit of a master's degree and the completion of our Systems Engineering Health and Visualization Capstone Project. We thank you for your contributions to our success and we share these Master of Science in Systems Engineering and Engineering Systems degrees with you. The team, jointly and individually, could not have made it without the support of each of you. Again, we give our heartfelt thank you.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

This introduction provides a project overview that includes a problem statement and the current state of the system operation as it applies to the stakeholders. It contains a background discussion, which includes information about the literature review, team organization, stakeholders, project objectives, and initial research questions. Finally, also included is an approach section that captures the project approach, Systems Engineering (SE) approach, and SE Process.

A. PROJECT OVERVIEW

This project overview will describe the problem statement; as it highlights the boundary of the problem scope. Also, included, is a review of the current system operational state with respect to the stakeholders to help emphasize the need for an improved system solution.

1. Problem Statement

The Space and Naval Warfare (SPAWAR) Atlantic's (SSC-A's) engineering leadership does not have adequate visibility into the Systems Engineering (SE) health of its programs necessary to make timely and accurate decisions concerning potential program risks and/or possible mitigation strategies. SSC-A currently performs manual data calls to obtain information required to assess a project's current state of systems engineering health. SPAWAR leadership also lacks a means to measure the quality of SE work for the projects and programs being executed at the command. With an ability to access, store, and analyze the right program information, leadership could gain insight into potential systems engineering risk areas and be proactive in resolution of issues that lead to program failures or reduced capabilities.

2. SSC-A's Current State

Currently, SSC-A's leadership conducts manual data calls to obtain necessary SE and SE Management information. A System Engineering Health and Visualization (SEHV) capability is needed to save time, effort, and ultimately costs by capturing the

required information more efficiently. The information requested trickles down to lower echelons and eventually to the system engineer. In addition to the system engineer's daily activities, response to leadership requested data calls is often expected. This takes quite a bit of time when there are multiple projects from which to collect data. An individual actually has to manually track down the information requested from each project and analyze this information to ensure the correct data is delivered to leadership. Figure 1 displays the SSC-A's current state (without SEHV), SSC-A's SEHV Current State, highlights the manual data call process as it exists today.

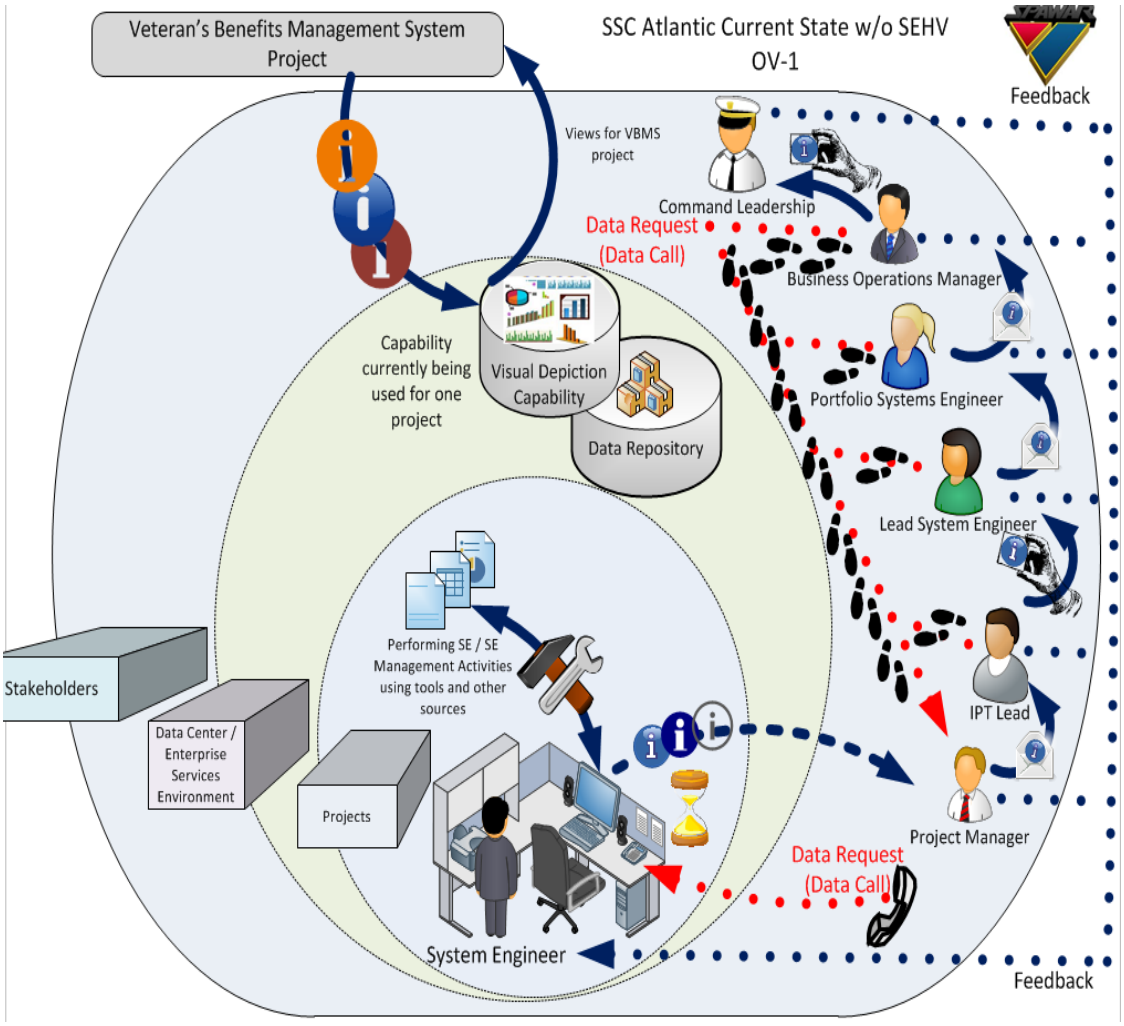


Figure 1. SSC-A's SEHV Current State

Having too many people in any process can increase the chances of an unsuccessful data call. Leadership's data call requests trigger meetings for data collection. The frequency and duration of these meetings can be decreased significantly by capturing this data via an automated process. As manual information gathering tactics are taking place, the data call request is usually funneled down to a lower echelon that can provide the data requested. This process can take time, especially when higher priority / mission critical tasks are being performed by the information holder. Individual projects currently have a system engineer who uses tools to perform SE / SE management activities. Once the system engineers provide the information to their chain of command, there can be positive or negative feedback given to that system engineer regarding the data provided.

The Veteran's Benefits Management System (VBMS) project is an example within the SSC-A organization that uses visualization software to depict graphical images of metrics for their team's use. The VBMS team uses this type of software with a data repository within SSC-A's Data Center / Enterprise Services Environment. This same automated methodology can be used to solve the data call dilemma currently being experienced at SSC-A. All stakeholders requesting these measures tend to want to see some sort of visual trends so this existing system provides an excellent starting point.

B. BACKGROUND

This background section discusses historical material that could have been impacted differently with the support of the capability that this capstone report presents. The evaluation of the literature related to this topic and used to tailor solutions for the project stakeholders is reviewed. The team organization as well as stakeholders' identification for this capstone is provided. Finally, the project objectives and the identified initial research questions are discussed.

1. Project Background

SSC-A was highly in need of a comprehensive understanding, through dynamic displays, of the overall health of its SE process areas against prescribed performance measures. SSC-A has the need to access specific SELIs to provide decision-makers

dynamic and current visibility into quality and effectiveness of SE / SE management activities. The capability is expected to assist SSC-A in the identification and diagnosis of potential SE / SE management problems either before they occur in order to mitigate them or after they occur in order to prevent like problems in the future.

The data housed in SSC-A's existing SE toolsets only provide a snapshot of the status of the project at the moment in time when the data is requested. SSC-A does not have visual trending representations of the status of SE management processes that can provide visibility into expected project performance and potential future states. An audit trail of data needed to be captured, stored, aggregated, and analyzed from the various projects in an automatic or non-disturbing fashion to display the respective trending status. The SEHV team proposed various visual representations of the data in order to illustrate the measures extracted from projects to provide SEHV stakeholders an indication of potential future project states.

SSC-A strives to offer continuous process improvement when providing quality systems to stakeholders. The command's goal is to be more proactive identifying system health indicators during early phases of system development. The savings from early identification and monitoring of system health could have been realized in the following examples if an SEHV capability had been present. The Defense Information Management Human Resource System (DIMHRS) is a failed project that did not have proper insight into SE health issues. Almost 1 billion dollars was spent on DIMHRS and still the project failed to deliver the capability promised. The deliverables were supposed to be used across all Department of Defense (DOD) branches of service but ended up only being used by the Army and Air Force. The lack of written requirements and configuration management control were responsible for the issues with DIMHRS. Leadership of DIMHRS directed engineers, on several occasions, to develop the project and forego the documentation until later. Each branch of service wanted it tailored to suit its respective needs. This fueled unrealistic schedules and continuous requirement changes. The resulting outcome of the DIMHRS project came nowhere near the overall expectation (Ugone 2010).

Had System Engineering Leading Indicators (SELIs) been used on the DIMHRS project, specifically using requirements trends (SELI 1), the failure outcome could have been projected prior to realization. As stated in the previous paragraph, "the lack of written requirements" was one of the biggest issues that were identified as responsible for project failure. Had DIMHRS used requirements trends and kept track of them, the resulting outcome may have been successful. Because that there were no requirements trends being tracked, there was no way to test validation (SELI 4) and verification (SELI 5) of the project. Furthermore, using Risk Exposure trends (SELI 9), Risk Treatment trends (SELI 10), and Process Compliance Trends (SELI 12) might have helped forecast the risks and identify options to correcting them. The Process Compliance trends would have also aided in maintaining configuration management. Had the SEHV process been applied to the DIMHRS program, as stated, the program might have been completed on time and under budget.

SSC-A has also developed human resource systems, such as the Navy Standard Integrated Personnel System (NSIPS), the Career Information Management System (CIMS), and the manpower control system, Total Force and Fleet Manpower System (TFFMPS), all of which span the complete software development life cycle from conception to sustainment. SSC-A developed the Veteran Affairs' (VA) Veterans Relationship Management/Customer Relationship Model (VRM/CRM) and a Master Veteran Index (MVI) system and has integrated these systems with numerous other legacy VA systems. There are several other projects that are in progress that include concept refinement, development, integration, and potential sustainment of software that are within different stages of the project life-cycle that could truly benefit from this type of capability. The SEHV solution provides the ability for each individual project to explain its own unique representative systems engineering status in order for automated analysis of project health to be identified and visualized to command leadership.

Most of these programs, if not all, were rated as semi-successful to successful projects. However, NSIPS is highly modified using custom coding rather than using COTS software by PeopleSoft, now Oracle code. Had all these programs with NSIPS used Interface Trends (SELI 3), Risk Exposure Trends (SELI 9), Risk Treatment Trends

(SELI 10) and Architecture Trends (SELI 17), they may have been more successful than they are today. By using SELI 3 and SELI 17, there would have been a better architecture in place and fewer problems when Oracle updated its systems including less interface problems with each new version. The use of SELI 9 and SELI 10 could have exposed risks and possibly provided insight on what was necessary to mitigate them properly. The same applies to CIMS since it is part of NSIPS.

TFFMPS might not have been shelved had it utilized the risk and interface trends. Following the guidance of SELI 3, SELI 9, and SELI 10, TFFMPS may have been in production today. The biggest issue found with using TFFMPS is that it cannot interface with an excel document into an Oracle/PeopleSoft COTS product. A fit gap analysis of the excel spreadsheet to use in the COTS product should have been conducted to make this determination early in the life cycle.

VRM/CRM and MVI used a modified Agile system and followed it as planned, a modified Agile system is defined as a combination of a Waterfall and an Agile development plan using good engineering practices. Certainly, the architecture could have used some modifications. The architecture could have been improved had it used SELI 3 and SELI 17. If SELI 3 and 17 had been considered when relating legacy systems to the new system, VRM/CRM and MVI risk exposure and treatment plan would not have been so extensive to overcome most of the interface issues.

2. Literature Review

A literature review was conducted and eventually prompted the use of International Council on Systems Engineering (INCOSE) SELIs Guide version 2.0 as the major guidance for the capstone effort. The team's initial research consisted of exploring and reviewing different publications, briefs, and artifacts related to measurement of SE management processes. The team's initial review provided insight on how SE metrics are currently being utilized and what information is being revealed.

MIT previously conducted research to determine how to use SE metrics to identify problem areas and to predict trends. The study breaks down characteristics of what constitutes a leading indicator and its specific usefulness. Objectives and goals were also contained within the document (Rhodes, Valerdi and Roedler 2008).

Paul Montgomery and Ron Carlson provided, in an NPS literary work on April 30, 2010, a discussion about the Applied Leading Indicators (ALI) SE tool. Data analysis features were illustrated that Naval Air (NAVAIR) used for their SE process areas. Historical metrics were obtained and analyzed to support the goal of predicting future performance (Montgomery and Carlson 2010).

INCOSE's SELI Guide version 2.0 technical product identified leading indicators that were associated with various parts of the project life cycle and include work from reputable sources such as the Massachusetts Institute of Technology (MIT), Lockheed Martin Corporation, INCOSE, the Lean Aerospace Initiative, the Systems Engineering Advancement Research Initiative, as well as Practical Software and Systems Measurements (PSM). Trends and various measurements were defined within the technical product to provide examples of needed metrics. The ALI tool was briefly discussed and its capabilities/limitations were clearly defined (INCOSE et al. 2007), (INCOSE et al. 2010).

3. Team Organization

Figure 2 provides the high-level organizational structure chart for the SEHV Capstone Project.

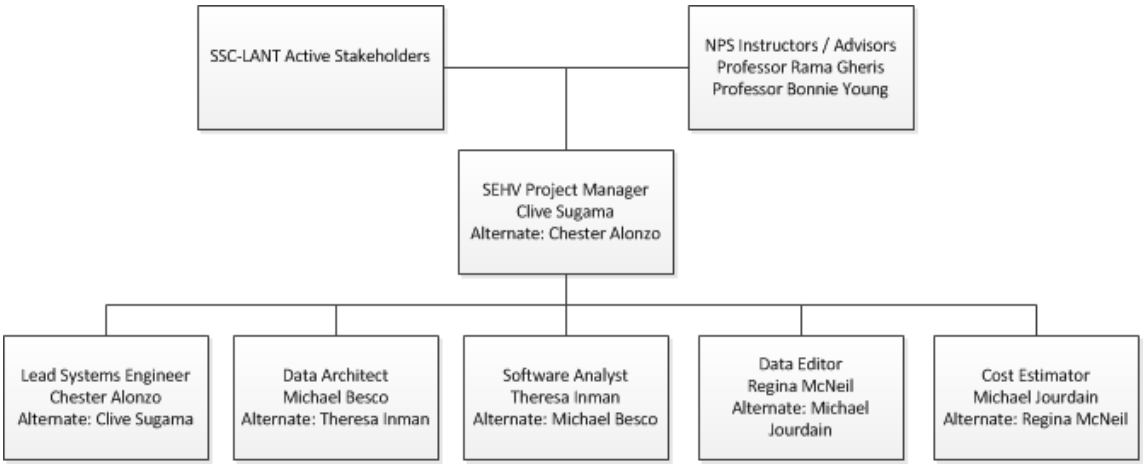


Figure 2. SEHV Capstone Organizational Structure

The SEHV team was organized according to key activities necessary for completion of the project. Each activity had a primary and alternate team member assigned. The key activities for this project were project planning, requirements development and validation, mapping of data elements to tools, SELI metrics analysis, cost estimation, process modeling, risk assessment, identification of use case scenarios, and an analysis of proposed metrics and process sets. The capstone advisors reviewed the scope, organization, quality, and schedule of the project and provided feedback on a regular basis. The team engaged with the stakeholders to identify use cases, requirements, and their priorities. Table 1 lists the SEHV team roles and responsibilities and identifies each team member(s) assigned.

Table 1. SEHV Capstone Project Team Roles and Responsibilities

Team Member	Roles and Responsibilities
Project Manager and Project Technical Risk Analyst: Primary-Clive Sugama Alternate-Chester Alonzo	Responsible for planning, monitoring, and controlling activities of the project. Lead development of the PMP. Responsible for Project / Technical Risk Analysis and Configuration Management (CM). Assisted with identifying key stakeholders and facilitated discussions with stakeholders for the purpose of capturing requirements, use cases, and metrics priorities.
Lead Systems Engineer (LSE): Primary-Chester Alonzo Alternate-Clive Sugama	Lead the elicitation, documentation, and organization of the stakeholder requirements. Captured system use cases from the various stakeholders. Tracked and managed the interfaces for the architecture. Tracked and managed the activities performing the verification and validation of the requirements, design, and architecture.
Data Architecture Lead: Primary-Michael Besco Alternate-Theresa Inman	Lead the development of the architecture for the system. Lead in identifying leading indicators that would indicate the health of system engineering efforts within SSC-A. Additionally, developed the entity-relationship architecture from the SE tools that will map data to the leading indicators.
Software Analyst: Primary-Theresa Inman Alternate-Michael Besco	Analyzed the implementation of the architecture. Interfaced with the Architecture Lead from SSC-A Enterprise SE Tool Suite group to determine the data elements that were harvested from the selected tool suites and recommended a data strategy for the automated collection, storage, and archival of the data.
Data Editor: Primary-Regina McNeil Alternate- Michael Jourdain	Ensured all documentation was formatted, consistent, and contained the information pertinent to that deliverable. Enforced the standards set by the NPS Thesis Processing Office on this SEHV project report.
Cost Estimator: Primary-Michael Jourdain Alternate-Regina McNeil	Provided cost and benefit analysis on the SEHV capability recommendation. Analyzed costs associated with implementation of metric data collection and provided cost projections associated with SEHV development.

4. SSC-A Active Stakeholders

Figure 3 displays the Operational View (OV-4) of Active Stakeholders which identifies roles within the SSC-A organization that were involved in the use of the SEHV System.

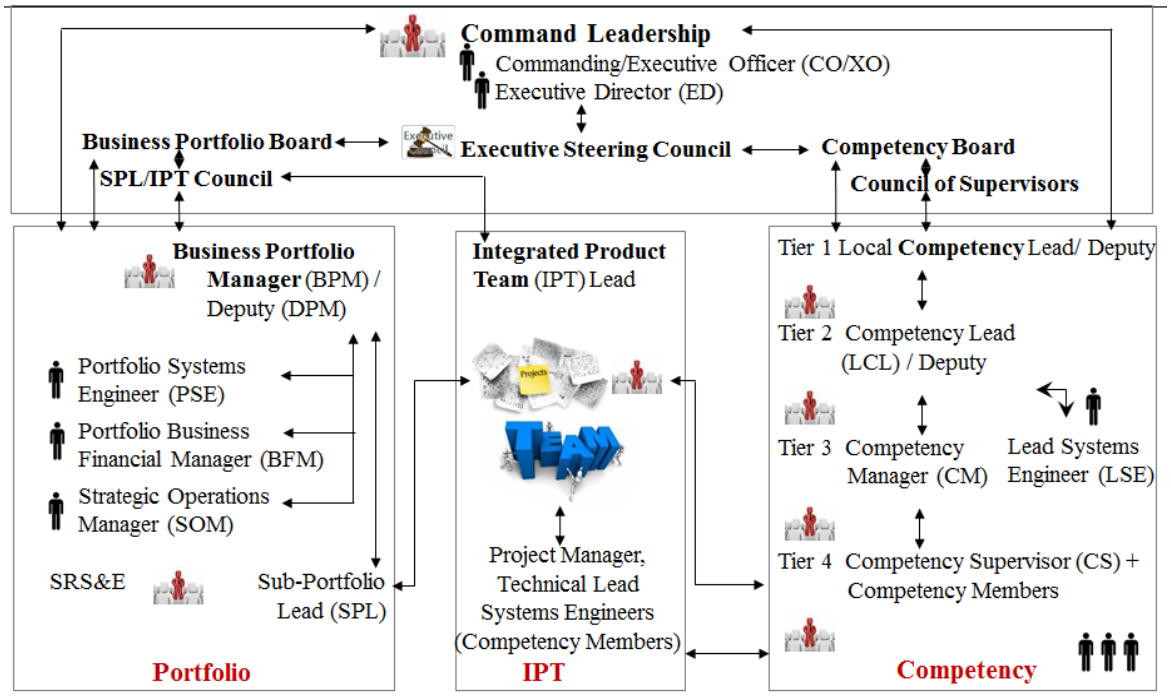


Figure 3. OV-4 SSC-A Active Stakeholders

5. Project Objectives

The objectives of this Capstone Project were to develop the requirements, architecture, data strategy, and conceptual model for the SEHV capability. The SEHV capability context diagram in Figure 4 illustrates the proposed SEHV capability and helped the team to bond the project objectives and scope. Projects were the source of the data elements for both the SE / SE management data elements. SE / SE management tools or other sources were used to generate these data elements. The SEHV capability that is housed within the Data Center / Enterprise Services Environment (DC/ESE) used the guidelines within the INCOSE SELI Guide version 2.0 to depict project trending data to

SEHV stakeholders. The stakeholders were able to review these SELI trends using data collected from projects and provide feedback.

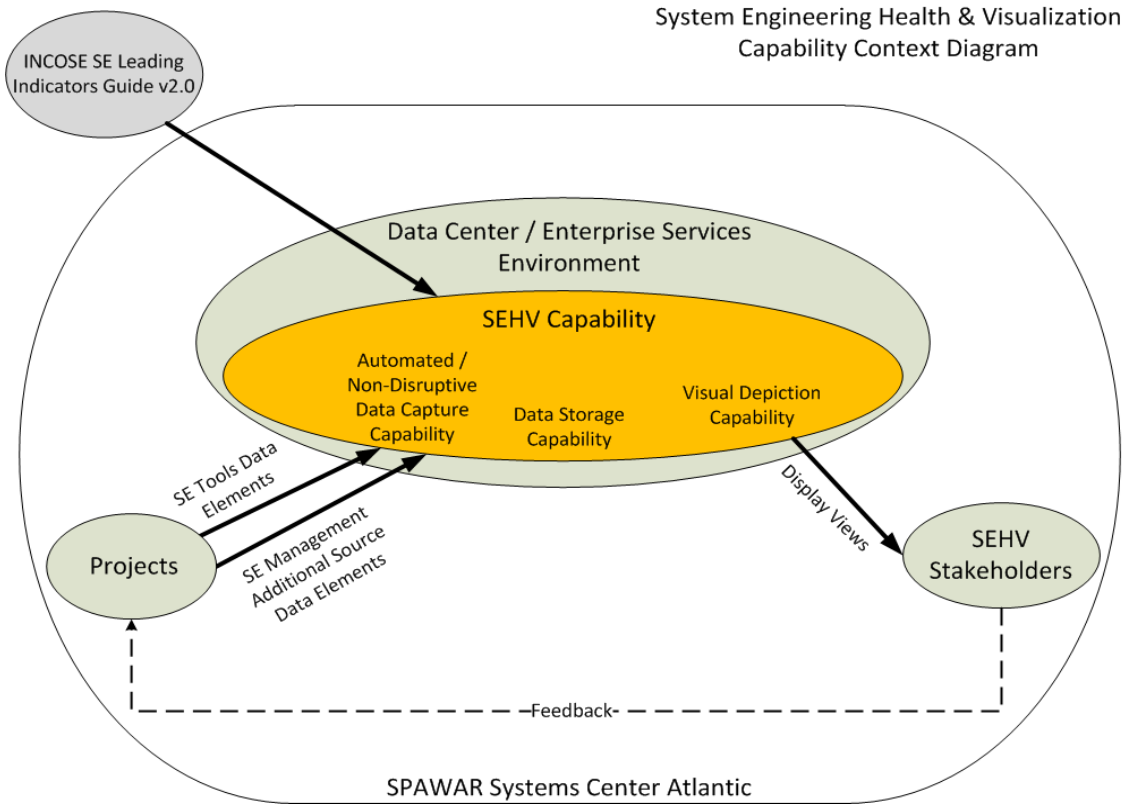


Figure 4. SEHV Capability Context Diagram

Figure 5 displays the OV-1 which illustrates the SEHV capability. The system engineer and project team allocated to a specific project produced data using SE / SE management tools. The data elements from these tools and other sources were harvested or collected by non-disruptive means and kept in the data repository located within the DC/ESE at SSC-A. The VBMS project has a Visual Depiction Capability and Data Repository within the DC/ESE which was leveraged for the SEHV capability. This capstone project researched means to utilize these capabilities to the fullest when introducing the SEHV capability. SELI analytics will be a core piece of the visual depiction capability. The visual depiction capability provides displays of SE health to SEHV stakeholders in order to initiate and facilitate feedback to the system engineer of a project.

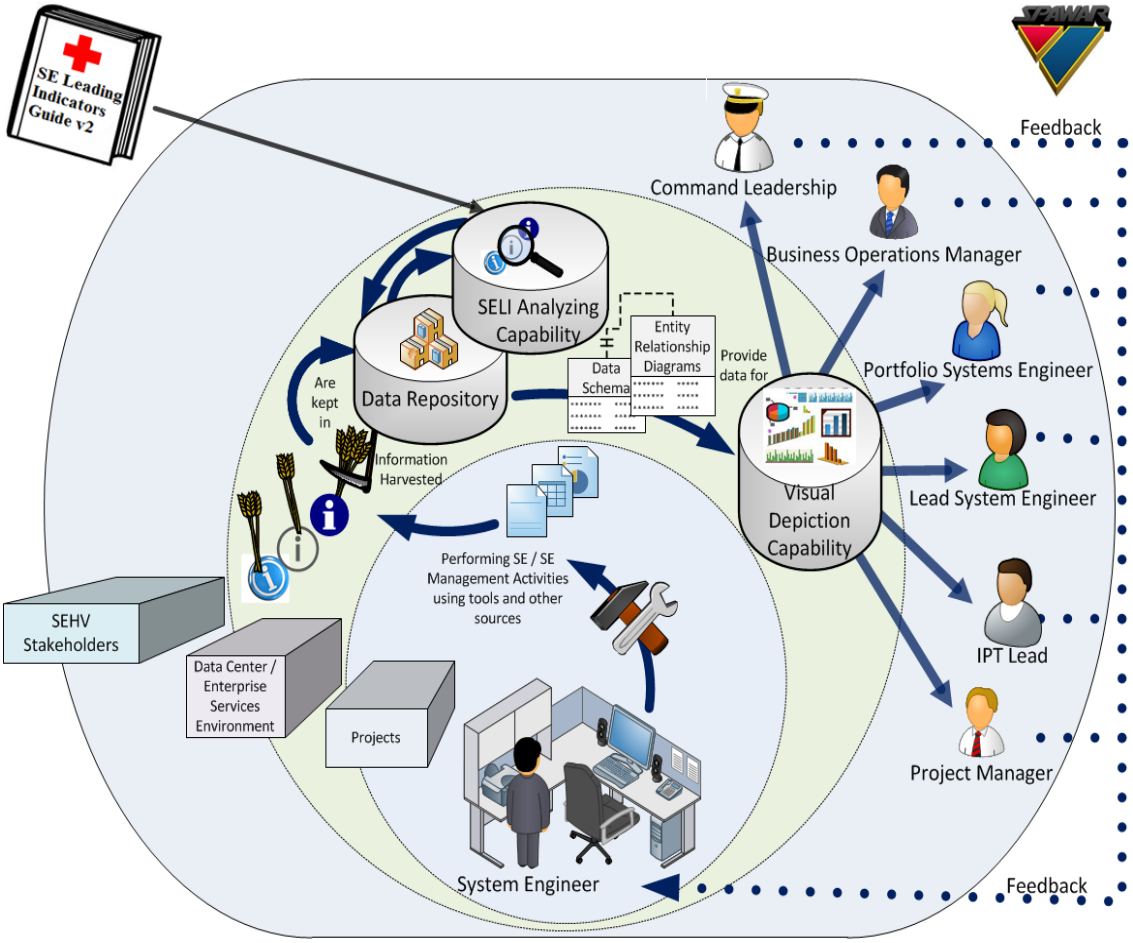


Figure 5. SEHV Capability OV-1

Key SE health metrics will provide insight into the quality and effectiveness of SE activities which support command objectives of consistent solution delivery and customer satisfaction. Functional and physical architectures will support a depiction of the collection, evaluation, and dissemination of relevant dynamic data elements that supported the validated SELI measures. The architecture will also support temporal and pattern analysis of the data elements. A method to ingest the identified data elements into the SEHV data repository, in an automated manner, will be included.

6. Research Questions

Working with the stakeholders' requirements and current state of technology, the SEHV team developed system engineering research questions that guided the research

and the system conceptual design. These questions formed the basis for understanding stakeholders' needs and system goal of this project. The answers can be found in Appendix D.

Data Sources

- Which tools and supporting processes capture the data elements needed to ingest into the SEHV solution?
- What engineering tools are being leveraged?
- What data sources are available?
- What data elements are needed?
- What tool data is most dependable or valuable?

Data Collection

- How is data currently being captured?
- How will the automatic collection work?
- If the data cannot be collected automatically, can the SELI data elements be collected on some sort of schedule?
- How easily can one collect any specific piece of data?

Data Storage

- How are these data elements (individual pieces of data) related to one another?
- What questions will be asked of the data?
- How long will the historical data need to be stored?

Data Analysis

- Can a process be constructed to avoid data calls?
- What calculations need to be performed on the data elements?
- What trending patterns are being looked for in the data?

Data Display

- What visualizations best represent the data?

SEHV Stakeholders

- Who are the stakeholders that need to view these SELIs?

SELIs

- What are the top SELIs that will provide the most insight to leadership for determining how well the SE project is going?
- Which SELIs do the stakeholders find most-useful?

Other Topics

- What is good systems' engineering / management? Is it similar to good project management with ensuring the SEHV system functions satisfy stakeholder requirements?
- How are other similar commands monitoring SEHV? (Ex. SSC-PAC, NavFac, NavAir, Army Corps., AF ESC)
- How much will it cost to collect SELI data elements?
- How long should it take to obtain a required visualization?
- How many metrics or trends should be viewed?

C. APPROACH

Due to the complexity of the stakeholders' needs and current state of technology, the SEHV team agreed on the encompassed project approach and system engineering process for the development of the proposed SEHV system.

1. SEHV Project Approach

The SEHV team analyzed SE leading indicators to facilitate project risk identification. The team studied the INCOSE SELI Guide version 2.0. This guide was used as a control for this project. This guide identified 18 leading indicators that provided consistent insight into future project performance. The use of the SELIs ensured levels of

quality for the solution. SELIs were reviewed and assigned priorities based on their impact to project cost and schedule, and system performance as well as their ability to answer common questions by engineering managers concerning system risks. Table 2 lists the 18 SELI trends documented in the INCOSE SELI Guide version 2.0.

Table 2. SELI Trends

SELI 1. Requirements Trends
SELI 2. System Definition Change Backlog Trends
SELI 3. Interface Trends
SELI 4. Requirements Validation Trends
SELI 5. Requirements Verification Trends
SELI 6. Work Product Approval Trends
SELI 7. Review Action Closure Trends
SELI 8. Technology Maturity Closure Trends
SELI 9. Risk Exposure Trends
SELI 10. Risk Treatment Trends
SELI 11. Systems Engineering Staffing and Skills Trends
SELI 12. Process Compliance Trends
SELI 13. Technical Measurement Trends
SELI 14. Facility and Equipment Availability
SELI 15. Defect and Error Trends
SELI 16. System Affordability Trends
SELI 17. Architecture Trends
SELI 18. Schedule & Cost Pressure

The SEHV team's project approach to uniquely defining and applying the 18 SELIs was based on criteria such as the interest in the SELI by multiple stakeholders, ease of automating the method of capturing the data elements that support the SELI, tool availability that would produce data elements that support the SELI, having existing and available SE / SE management tools, and the cost of tools. The data collection process of the SELI choices documented how much an automated solution that harvests the SELI measures would be able to reduce expended time. Once data was collected, data visualization options were researched to be able to display trends of SELI measures. Figure 6 shows the SEHV project approach which includes SELI choices, data collection process, and display mechanism options which result in the final SEHV recommendation.

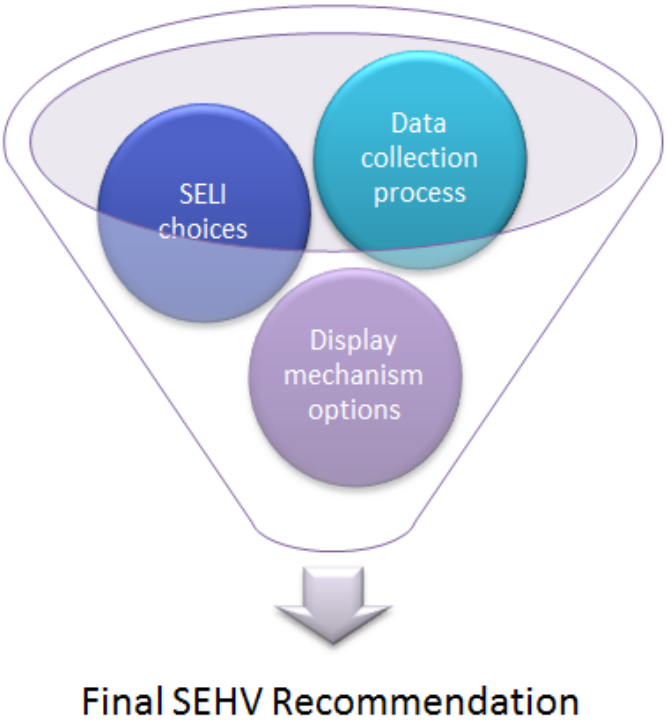


Figure 6. SEHV Project Approach

2. SEHV SE Approach

The SEHV team utilized an SE approach derived from the IEEE 1220_2005 Systems Engineering Process. This process was appropriate for this project since the approach produced documents and models versus hardware or software. Using this process helped facilitate the project's expected process environment, interfaces, work products, and necessary SE tools needed for the SEHV capability. This process began by obtaining SSC-A stakeholder inputs, then going through the SEHV SE process, and ultimately concluding with a recommendation (based on weighted criterion) of SELI choices that described data measure collection methodologies and their respective display mechanisms.

The SE approach input included evaluating SSC-A's requirements for an automated solution that can display project's SE trends that utilize leading indicators to suggest potential project risk. Evaluation of design requirements took place to include

identifying key SE / SE management data elements used to produce SE trends. Functional and nonfunctional requirements were also decomposed and validated to ensure the SEHV capability was within the scope of the NPS capstone.

The analysis approach began with defining the problem of SSC-A's limitation of not being able to determine a project's SE status in a timely manner. A literature review resulted in multiple sources pointing to INCOSE's SELI Guide version 2.0. It describes specific data elements needed in order to produce SE trends that expose potential risk areas. To determine the appropriate criteria for SSC-A, the Competency Aligned Organization (CAO) Concept of Operations (CONOPS) and Integrated Product Team (IPT) handbook were used to evaluate which SELI would be most important to a particular role within the organization. Evaluating techniques such as selecting most valued SELI and defining modeling requirements contributed to construction of Integration Definition 0 (IDEF0) architectures for particular SELIs. The use of actual data was not able to be obtained from sources such as Navy Enterprise Resource Planning (NERP), but expected data elements were used to produce examples of SE trends over time. A simulation was created using input variations to display a plethora of results for analysis. Risks, assumptions, and other applicable criteria were analyzed based on the capstone project's findings, and recommendations for the SEHV solution options were provided based on analysis results.

An overall analysis of the SEHV solution including the necessary features and requirements needed for the SSC-A organization to produce this needed capability was performed. Recommendations which result in decisions to move forward with the SEHV solution were documented to facilitate appropriate action for funding a prototype for this effort. The resulting capstone output includes this report that serves as a firm foundation for the SEHV capability.

3. SEHV SE Process

Requirements analysis and validation included needs analysis, stakeholder analysis, SELI prioritization, data source identification and an overall requirements review. Needs analysis included determining the need of SSC-A stakeholders of having

consistent command-wide visibility of projects to determine potential project risks. Stakeholder analysis was used for organizational structure which a OV-4 was developed. SELI prioritization was facilitated by SSC-A authoritative documentation such as the CAO CONOPS and IPT Handbook to satisfy schedule requirements of the SEHV Capstone. Data source identification showed required data elements for SELI visualization trends.

Functional analysis and validation included defining data collection, identifying supporting processes, completing IDEF0 modeling and a design review. Defining the data collection was pulling the required data elements to support SELI trends from SE software tools. SE / SE management would routinely input data within the tools to provide up to date data collection by the SEHV system. Identifying supporting processes was required for the SEHV methodology to use features such as capture, store, analyze, and display SELI trends. IDEF0 modeling was performed using SPEC Innovations Innoslate to illustrate a functional architecture of the SEHV system with respect to the chosen SELIs. Entity Relationship Diagram (ERD) modeling would represent relationships within the SEHV system to understand interaction between neighboring components. A use case analysis was planned for the design verification phase to simulate the SEHV system in action.

Design verification consisted of creating an experimental architecture, modeling historical project data, performing statistical analysis, and proposed visualizations / graphs. Creating an experimental architecture was done by Imagine That Inc.'s ExtendSim to simulate a manual data call process along with the proposed SEHV process. This simulation would prove the SEHV process is more efficient than the current manual data call process. Modeling historical project data would be necessary by obtaining data elements from SE tools over a period of time in order to show visual trending information. A repository to keep historical project data would be required to depict positive or negative SELI trends over time. Performing statistical analysis was done by SAS Institute Inc.'s JMP software to determine the frequency of SE tool usage within the SEHV process. A minimum amount of SE tool usage was determined to provide fresh data. Proposing visualizations and graphs would include notional examples

where possible displays could be used for the SSC-A SEHV initiative. Figure 7 displays the SEHV SE process.

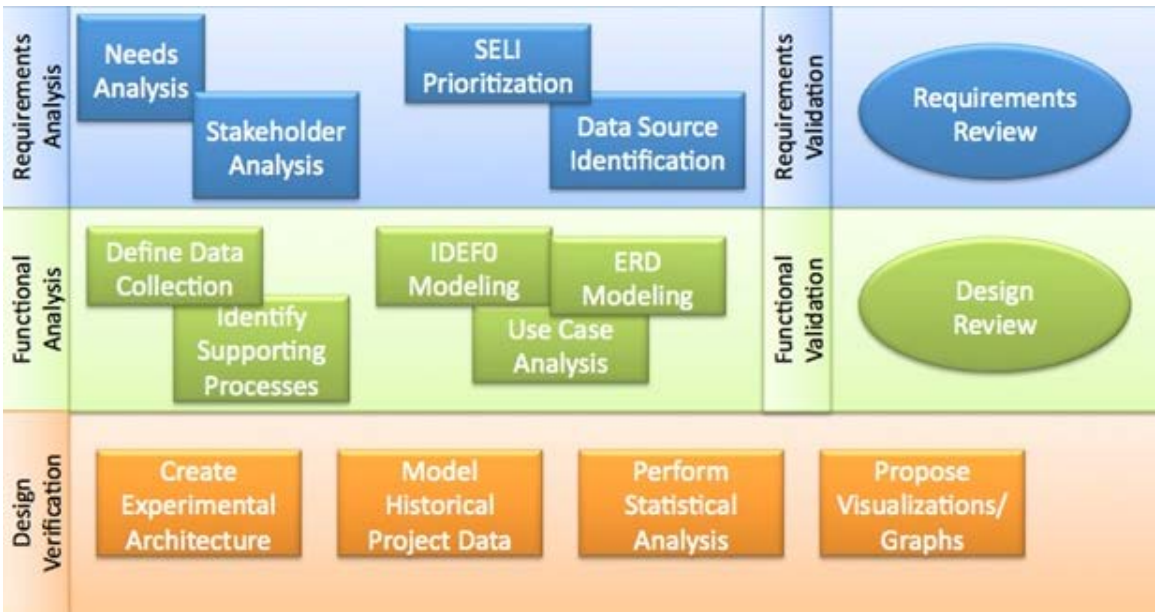


Figure 7. SEHV SE Process Diagram

The five functional blocks in Figure 8 represent a high level grouping of the activities outlined in the SE process in Figure 7. These SE processes were derived and tailored from the IEEE 1220–2005 Systems Engineering Plan (SEP). It also categorizes when each of the high level functions occurred within the three quarters allocated to this capstone project. Figure 8 displays a description of activities performed for Problem Definition/Needs Analysis, Requirements Analysis/Metrics Analysis, Functional Analysis, System Architectural Modeling, and System Analysis.

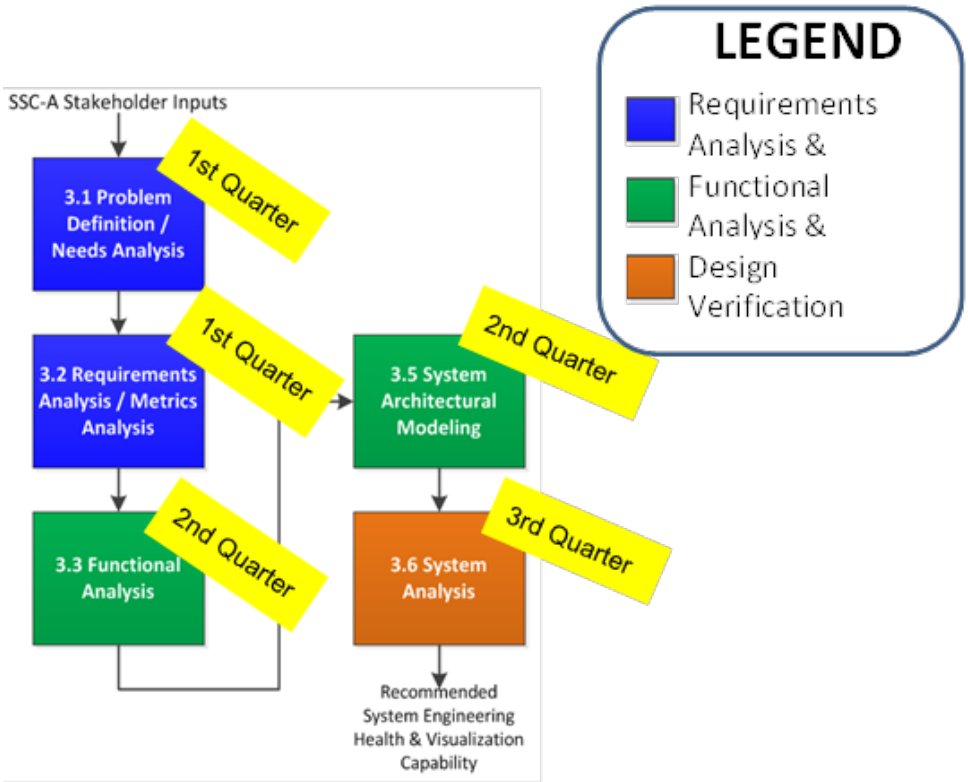


Figure 8. SEHV High Level Project Plan

a. Problem Definition/Needs Analysis

The team defined the problem and performed a needs analysis for the SEHV capability. This included conducting the stakeholder needs analysis, completing an analysis of SSC-A current capabilities, and providing examples of programs that have failed or had issues as a result of a lack of insight into their SE health. Analysis of the SEHV capability needs determined the overall boundaries, limitations, and constraints.

SSC-A needed dynamic displays to illustrate the overall health of its SE process areas against prescribed performance measures. SSC-A has a need to assess specific SELIs to provide decision-makers dynamic and current visibility into the quality and effectiveness of its SE/SE management activities. The capability assisted SSC-A in the identification and diagnosis of potential SE / SE management problems either before they occurred to mitigate them or after they occurred in order to prevent like problems in the

future. The entry criteria included SSC-A stakeholders inputs; and the exit criteria included documented stakeholder needs.

b. Requirements Analysis/Metrics Analysis

The team performed requirements analysis that resulted in a functional requirements baseline for the solution. Requirement analysis began with ensuring that the SSC-A stakeholder's needs were adequately documented, understood, and suitable for refinement. These were reviewed against the project criteria, and agreed upon by the SSC-A active stakeholders, NPS advisors, and the SEHV Capstone Project team. The SEHV team analyzed SEHV leading indicators to facilitate project risk identification. The team studied the INCOSE SELIs Guide version 2.0, used as a reference for this project. The INCOSE SELI guide identified 18 leading indicators that have been proven to provide insight into future project performance. The use of the SELIs ensured levels of quality for the solution. SELIs were reviewed and prioritized based on their impact to project cost and schedule, system performance, as well as, on their ability to answer common questions posed by engineering managers concerning system risks. The entry criteria included the project need statement; and the exit criteria included a stakeholder analysis, documented SEHV solution functional requirements, and a prioritized listing of SELIs based upon SSC-A stakeholder needs.

c. Functional Analysis

The automated SEHV solution will consist of functions such as capture, store, analyze and display. These functions will perform in an environment where other existing SSC-A tools will be present. The tools such as NERP, Total Workforce Management System (TWMS), Demand Signal Tool, and Risk Exchange will help nurture the SEHV system with the information it needs. Capturing data from these tools would involve a request from the SEHV user interface requesting the desired data. This information will be stored along with the users' input into a data repository. The SEHV analyzing capability would perform basic arithmetic to sum up the values of the data. In most cases this is a comparison of user planned information versus actual values provided by SE /

SE management tools. The SEHV analyzing capability would also set arrays of data for the display function to manipulate the data into a visual depiction.

The SEHV team developed an IDEF0 diagram and an ExtendSim simulation as part of the functional analysis. The entry criteria of the functional analysis section included the data elements, data sources, and notional trending patterns of the most valued SELIs. The exit criteria included an IDEF0 diagram and ExtendSim model depicting data capture methods, user input triggers, storage strategies, data analyzing functions, and visualization features.

d. System Architectural Modeling

The team continued to refine the SEHV context diagram, as well as, the SSC Current State and SEHV Capability OV-1 diagrams. The team developed an architecture model to be used to facilitate development of the SEHV capability. Functional and physical architecture models were created to assist in implementing the SEHV capability. The functional architecture model is solution neutral while the physical architecture model contains components that were evaluated against specific criteria such as cost, availability, and feasibility. The team developed an ERD to define the physical data model of the prospective relational database structure. The entry criterion included SEHV IDEF0 diagrams, positive, negative, and neutral SELI trending patterns, and data elements with associated source information. The exit criteria included a functional architecture that allocated SEHV functions to specific components, as well as, an ERD that facilitated the storage and analysis of the SEHV dataset.

e. System Analysis

The team performed an assessment of the SEHV capability against the functional requirements and operational use cases. Historical project data was mapped to the proposed entity relationship model and the team analyzed the SEHV capability in identifying trends and insight into SE health. Notional graphs and dashboards were created to present the information captured within the SEHV solution to the stakeholders. The team performed a high-level cost analysis of implementing the system and a risk analysis to identify any risks that SSC-A may encounter in implementing this SEHV

capability. The entry criteria included the functional architecture and physical architecture and the exit criteria included a validated architecture against historical data and operational use cases along with potential visualization mechanisms.

4. Risk Management

A distinction was made between overall project risk management and IT system or application risk management. The project manager worked with the project team and project sponsors to ensure that risks were actively identified, analyzed, and managed throughout the life of the project. Risks were identified as early as possible in the project to minimize their impact. The steps for accomplishing this are outlined in the following sections. The PM or Risk Assessment Manager served as the Risk Manager for this project. The steps for accomplishing this are outlined in Appendix A.

THIS PAGE INTENTIONALLY LEFT BLANK

II. REQUIREMENTS ANALYSIS

Perhaps one of the most challenging efforts to be realized during this project was the requirements analysis process. After understanding stakeholder needs, the team elicited requirements to be analyzed and organized them by high level function. The decomposed stakeholder requirements are shown in the following sections. Next, a functional analysis using modeling software to connect required functional abilities which helped verify SELI interactions was performed. In the final section, due to the realization that performing full detail analysis for all SELIs would become a schedule risk for this effort, a down select of five commonly discussed indicators, at SSC-A, was performed.

A. REQUIREMENTS ELICITATION

The SEHV team elicited requirements from the SSC-A Stakeholders. The stakeholders articulated their high level requirements, which are listed in section 1. From these high level requirements, the SEHV team decomposed the high level requirements into the component functions that would be required for the system. Additionally, the SEHV team identified supporting functions that are required for the ongoing operations and sustainment of the solution, as well as, for the expected operating environment requirements.

The SEHV team performed functional analysis and allocation of the requirements within Innoslate version 3.0. Each requirement was documented and managed within Innoslate. The established requirements were analyzed by the team to ensure they were clear, concise, measurable, and testable. The full list of the system requirements baseline is documented in section 2 below.

1. Stakeholder Requirements

The SEHV team worked with SSC-A Stakeholders to produce the following high level requirements for the SEHV system.

- The system shall perform automated data capture

- The system shall use data elements that can be pulled from SE tools and other data sources
- The system shall provide leading indicator analysis
- The system shall display SELI trends
- The system shall apply SELI concepts

2. SEHV Decomposed Requirements

Decomposition was performed by further research and evaluation of industry best practice in the SE community as well using a specific application for SSC-A organizational functions. Requirements decomposition established one of the essential requirements traceability relationships. It shows how each layer of requirements contributed to the satisfaction of the layer above. It is this relationship that connected the conceptual design to the development of requirements (IBM 2013).

The below list represents the SSC-A stakeholder validated decomposed functional and supporting requirements applicable to the SEHV system.

SEHV Functional Requirements

1. Data Capture

   The system shall perform automated data capture

   1.1. Data Pull
   The system shall pull data from existing SE tool data sources

   1.2. Data Filter
   The system shall filter results pulled from interfacing data sources

2. Data Storage

   The system shall store captured data from SE tools databases

   2.1 Data NormalizationThe system shall transform data from external data sources into a standard format for storage

   2.1.1 Interfaces

   The system shall receive data from external data sources.

   2.1.1.1 Data Source: IBM DOORS

   The system shall receive data from IBM DOORS

2.1.1.2 Data Source: Risk Exchange

The system shall receive data from Risk Exchange

2.1.1.3 Data Source: JIRA

The system shall receive data from JIRA

2.1.1.4 Data Source: NERP

The system shall receive data from NERP

2.1.1.5 Data Source: TWMS

The system shall receive data from TWMS

2.1.1.6 Data Source: TAA

The system shall receive data from TAA

2.2 Data Commit

The system shall store data in the SEHV database

2.3 Manage Data Requests

The system shall receive data from external data sources at configurable frequencies

2.4 Transaction Logging

The system shall log database transactions

2.5 Database Search

The system shall provide a database search capability

2.6 Database Indexing

The system shall provide database indexing services

2.7 Database Backup

The system shall provide database backup services

2.8 Database Archival

The system shall provide database archival services

2.9 Database Recovery

The system shall provide database recovery services

2.10 Database Auditing

The system shall provide database auditing services

3. Data Analysis

The system shall perform analysis on the collected data

3.1 Perform Calculations

The system shall perform calculations on the captured data

3.2 Pattern Analysis

The system shall have the ability to identify specific patterns in the collected data

3.3 Statistical Analysis

The system shall have the ability to perform statistical analysis on the collected data

3.4 Time Based Analysis

The system shall have the ability to perform temporal analysis on the collected data

4. Data Display

The system shall display SELI trending graphs

4.1 Configurable Dashboard

The system shall allow the user to select a graph to view

4.1.1 SELI Graphs List

The system shall list SELI trending graphs that are available for use

4.1.2 Project Listing

The system shall allow the user to select from a list of projects, which are organized by portfolios and IPTs, to display on the graph

4.1.3 User Profile Settings

The system shall save user profile settings such as graph, project selection, and dashboard configuration

4.2 Provide SELI Visualizations

The system shall display SELI trending graphs.

4.2.1 System Affordability Trends

The system shall display System Affordability trending graphs

4.2.2 Process Compliance Trends

The system shall display Process Compliance trending graphs

4.2.3 Risk Exposure Trends

The system shall provide Risk Exposure trending graphs

4.2.4 Technical Measurement Trends

The system shall display Technical Measurement trending graphs

4.2.5 SE Staffing and Skills Trends

The system shall display SE Staffing and Skills trending graphs

4.2.6 Additional SELI Trends

The system shall be capable of handling up to 13 additional future SELIs

4.3 Administer SEHV Dashboard

The system shall allow privileged users to adjust exposed configuration settings from a web interface

4.3.1 Manage Graphs

The system shall allow a privileged user to add, edit, or remove the list of graphs available for use

4.3.2 Manage Portfolio/IPT/Project List

The system shall allow a privileged user to manage the hierarchical relationship of Portfolios/IPTs/and Projects

4.3.3 Manage Prediction Calculators

The system shall allow a privileged user to manage the calculations used within the graphs

4.3.4 Manage Users

The system shall allow a privileged user to manage the list of users and their roles

5. Supporting Infrastructure

The system shall provide the hardware and software infrastructure to support the solution

5.1 Web Application Hosting

The system shall provide web application hosting services

5.1.1 Concurrent Users

The system shall provide access to number of concurrent users which will have to be determined in the future

5.2 User Management

The system shall provide management of user accounts

5.2.1 Role-Based Access

The system shall implement role based access security

5.2.2 Authentication Mechanism

The system shall provide a user authentication mechanism which complies with all applicable information security and command security requirements

5.2.3 Restricted Access

The system shall prevent access of SEHV data by unauthorized users

B. FUNCTIONAL ANALYSIS

Functional analysis was performed with a Model-Based Systems Engineering (MBSE) approach. The functional model was created in Innoslate as an IDEF0 model. Innoslate assisted with the analysis of the model by providing metrics on its maturity by analyzing the decomposition of the functions; analyzing the requirements traceability and determining whether the functions had triggers or controls in place.

The five top-level functions are listed below.

1. Provide SEHV

The "Provide SEHV" function denotes the top-level function of the main application. "Provide SEHV" is decomposed by "Capture Data," "Store Data," "Analyze Data," and "Display Data" functions. The "Capture Data" function interfaces with external data sources. The "Store Data" function encapsulates all the component functions associated with data storage. The "Analyze Data" function decouples the logic layer from the data tier and allows the solution to be easier to maintain and upgrade component parts. The "Display Data" function includes the features that allow the user to access and interact with the SEHV system.

2. Perform SE Activities

The top-level "Perform SE Activities" function incorporates all of the associated processes that are external but related to the SEHV system. "Perform SE Activities" is broken down into four functions, which are "Request System Engineering Services," "Perform System Engineering Services," "Use SEHV to Assess System Engineering

Services," and lastly "Provide SE Process Guidance." External customers request systems engineering services from SSC-A via the "Request System Engineering Services" function. The activity of a systems engineer at SPAWAR working on a project is represented by the "Perform Systems Engineering Services" function. The "Use SEHV to Assess Systems Engineering Services" function is where 5.0 leadership at SSC-A analyzes the graphs produced by the SEHV system to evaluate the quality of systems engineering being performed. Armed with the trending data from SEHV for projects as SSC-A, 5.0 leadership now has sufficient data to inform decisions, such as, where to apply resources, determine where gaps in training are, or advertise to potential customers what SSC-A strengths are in order to get more systems engineering work in that area. Finally, the "Provide SE Process Guidance" functions represent the resources available to a systems engineer at SSC-A.

3. Provide SE Tools Functions

The "Provide SE Tools" function groups all of the SE toolsets that must interface with SEHV. The tools are listed by functions within "Provide SE Tools" in order to provide a level of abstraction. The subfunctions of "Provide SE Tools" are "Provide Requirements Management Tool Functions," "Provide Risk Management Tool Functions," "Provide Project Staffing Tool Functions," "Provide Process Compliance Tool Functions," "Provide Project Costing Tool Functions," "Provide Personnel Data Tracking Tool Functions" and "Provide Demand Signal Tracking Tool Functions."

4. Maintain SEHV

The "Maintain SEHV" function consolidates all of the functions that contribute to the maintainability of SEHV. The "Manage System Updates" subfunction tracks all corrective and preventative updates to the SEHV system. The "Manage System Configuration" subfunction ensures that configuration details of the SEHV system are easily managed and configurable. The "Manage System Interfaces" subfunction tracks the interface details for each external data source that interfaces with SEHV. The systems interfaces must also be easily managed and configurable. The "Manage Data Capture

Requests" subfunction manages the frequency that data is harvested from external data sources.

5. Host SEHV

The "Host SEHV" top-level function identifies the component functions that are required to host SEHV. These are the hosting services that would be required in order to host SEHV within the data center at SSC-A. The "Manage Database" subfunction is performed by a database management system. The database management system provides capability such as data indexing, data archive, data backup, and data restore. The "Manage Web Application" function is performed by a web application server. The web application server provides the capability to serve out the web application to remote users. The "Manage Users" function is performed by a user account management tool, such as Active Directory, and provides the capability to authenticate users to access the SEHV system. The "Manage Storage" function is performed by the storage volume that handles the storage of the SEHV data. The storage volume provides the capability to allocate adequate storage for SEHV as well as provide failover and redundancy in order to increase the reliability and performance of SEHV.

All associated IDEF0 models are provided as screen captures on a supplemental disc.

C. SELECTION OF LEADING INDICATORS

A leading indicator is a measure for evaluating the effectiveness of how a specific activity is applied on a project to provide information about impacts that are likely to affect system performance objectives. A leading indicator may be an individual measure, or collection of measures and associated analysis predictive of future systems engineering performance before the system is fully realized. Leading indicators aid leadership in delivering value to customers and end users, while assisting in taking interventions and actions to avoid rework and wasted effort. By analyzing the trends, predictions can be forecast the outcomes of certain activities. Trends are analyzed for insight into both the entity being measured and potential impacts to other entities. This provides leaders with

the data they need to make informed decisions and where necessary, take preventative or corrective action during the program in a proactive manner.

1. SELI Down Select Process

The SEHV team performed an SELI down select process to choose a subset of SELIs to analyze in depth. In order to comply with the capstone schedule requirements, the team selected five of the 18 SELIs to study. The team's intent was to study a subset of the SELIs that were of importance to the SSC-A organization and that would be representative examples whose results would be extensible to the full set. The subset of SELIs was chosen to lay the foundation of the SEHV methodology. All SELIs were considered important as indicators of SE health; however to successfully complete the Capstone report within the allotted time, the down select process was necessary to focus on a specific set of SELIs. The down select process allowed selection of SELIs based off of authoritative SSC-A documents which mapped organizational roles to these SELIs.

Mapping to Interested Stakeholders

SSC-A's organization involves various stakeholders with specific roles and responsibilities. The SSC-A Competency Aligned Organization (CAO) CONOPS and IPT Handbook released a new version of documentation in March 2014 which characterizes the organization's personnel. These documents have been advertised as the command's authoritative source of information. Descriptions of stakeholders were closely matched to the 18 SELIs listed in INCOSE's SELI Guide version 2.0. This enabled the team to determine which stakeholders were assigned responsibilities that incorporated risks depicted in INCOSE's SELI Guide version 2.0 to support down selecting the 18 SELIs. Figure 9 displays the most stakeholder associations between unique SELIs.

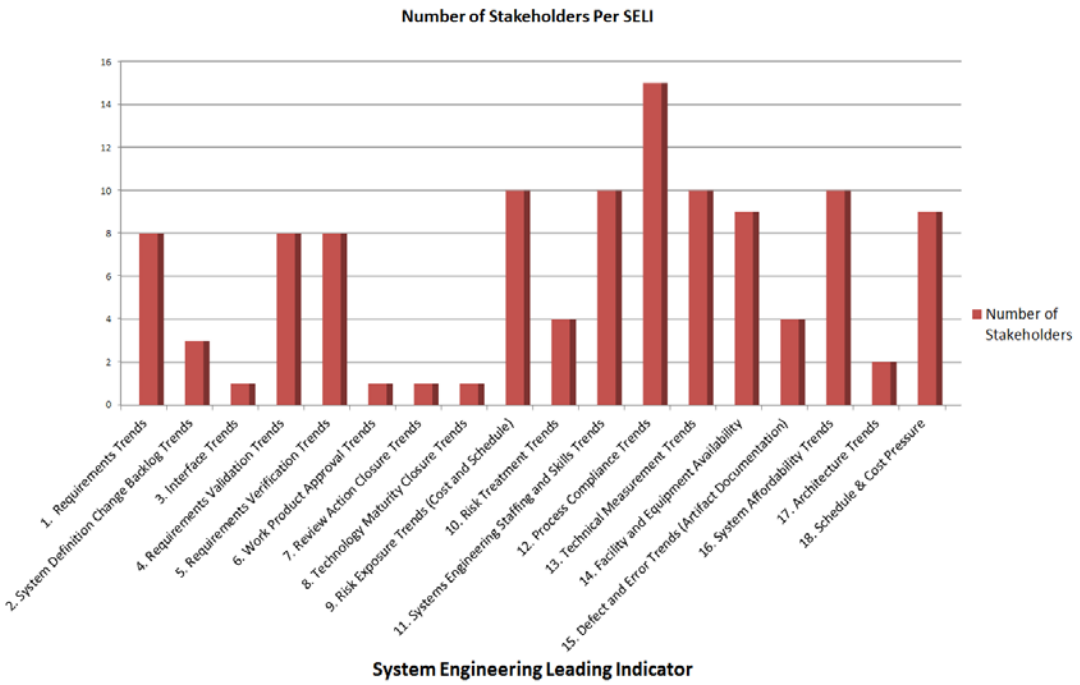


Figure 9. Most Valued SELI Based on SSC-A CAO CONOPS and IPT Handbook

The stakeholder to SELI analysis revealed that five of the 18 SELI listed in INCOSE's SELI Guide version 2.0 were most important to the SSC-A stakeholders based on the SSC-A CAO CONOPS and IPT Handbook. The five SELIs were Risk Exposure Trends (Cost and Schedule), SE Staffing and Skills Trends, Process Compliance Trends, Technical Measurement Trends, and System Affordability Trends. These SELIs were evaluated closely to support SSC-A's need for an automated SE / SE management risk visualization solution. SSC-A's CAO CONOPS and IPT Handbook Stakeholder characterization/mapping with respect to SELIs is found in Appendix C.

Further details on each of the SELIs selected for investigation in this report are in Chapter IV.

2. Current External Tool Sources

Current SE tool sources at SSC-A include software applications such as Navy-owned Navy Enterprise Resource Planning (NERP), Program Project Management and Control (P2MC), Civilian Personnel Information Management System (CPIMS), Mission

Alignment, Demand Signal, Team Assignment Agreement (TAA). COTS software such as IBM Rational Suite of tools, Atlassian Suite of tools, and several other less commonly used and possibly more specialized tools for specific modeling and simulation, maintenance and sustainment, or system configuration management are used as well.

Each project customer or stakeholder places a varied set of requirements on IPTs. Some project stakeholders mandate the use of a particular SE tool to easily transfer or understand data based on their particular needs. Other project stakeholders allow the engineers or other IPT members to select and use any tool that they prefer but may or may not be willing to fund such use. This variation has caused a culture within SSC-A where there is little consistency of standard SE Data collection. In order for SSC-A stakeholders to have a complete visualization of SELIs, SE data would need to be normalized, e.g., presented in a consistent format, regardless of which of the various tools were being used.

SSC-A is in the process of helping normalize the tools prior to tackling the effort of integrating and normalizing multiple SE Tool data streams. There is a current selection of tools identified to specifically provide the necessary SE Data fields required for analysis and visualization of SELI trends deemed most important to SSC-A leadership. Mapping the current planned tool selection roll out to the five selected SELIs, analyzed by this SEHV team, provided the basis for the data collection function of the SEHV analysis provided in the remainder of this report.

3. Stakeholder Roles and Descriptions

The following is a compressed view of the SSC-A CONOPS roles and descriptions. The detailed list with SELI mapping can be found in Appendix C.

Command Senior Leadership Staff
COMMANDING OFFICER (CO), EXECUTIVE DIRECTOR (ED)
DIRECTOR OF MANAGMENT OPERATIONS
DIRECTOR OF INTEGRATION AND EFFICIENCY
INSPECTOR GENERAL (IG)

Business Portfolio Board
BUSINESS PORTFOLIO MANAGER (BPM)

DEPUTY PORTFOLIO MANAGER (DPM)
PORTFOLIO SYSTEMS ENGINEER (PSE)
SUBPORTFOLIO LEAD (SPL)
INTEGRATED PRODUCT TEAM (IPT) LEAD
IPT TECHNICAL LEAD

5.0 Competency
TIER 1 LOCAL COMPETENCY LEAD (LCL)

LEAD SYSTEMS ENGINEER (LSE)
CONTINUOUS PROCESS IMPROVEMENT (CPI) LEAD
PROCESS OWNER
PROCESS MANAGER
COMPETENCY ADMINISTRATIVE SUPPORT

TIER 2 COMPETENCY LEAD (CL)

TIER 3 COMPETENCY MANAGER (CM)

TIER 4 COMPETENCY SUPERVISOR (CS)

FIRST-LINE SUPERVISOR

CONTRACTING OFFICER`S REPRESENTATIVE (COR)

Integrated Product Team
PROJECT MANAGER

III. SEHV ACQUISITION OPTIONS ANALYSIS AND SELECTION

Based on the above requirements and existing technology capabilities, the SEHV team discovered four potential acquisition options, one manual (the existing approach) and three automated, for providing the SSC-A SE Health and Visualization requirements. Each acquisition approach was evaluated using an AHP down select process which compared system functional area and cost as shown in the following figures below. The pairwise comparison charts and method to reaching the conclusion are also shown below in the following sections. Evaluation of each function included: Risks, Assumptions, Constraints, and Safety and Security concerns as explained in detail.

A. ARCHITECTURE OPTIONS

The two architectures options were a Manual Method and an Automated Method. The manual process of collecting data to provide SSC-A leadership information on data calls and project health is the existing process at SSC-A. The SEHV team explored and recommends an automated process to replace the manual process to improve efficiencies at SSC-A. Automated SEHV capability can be provided through several different acquisition options: Independent Commercial Off The Shelf (COTS) Tools (All COTS), Automated Centralized (GOTS) System and an Automated Hybrid Solution Set.

1. Manual Method

The manual method is defined as a non-automated collection of data. Management requires data on an individual electronic basis, requests this information from their subordinates; the subordinates request this information from their numerous team leads in a specific format. The team leaders collect and verify this information from each of their team members and send it up the chain of command for management analysis. The manual process of collecting SE data to search for indicators of project failures is currently the primary method used at SSC-A at this time. This existing manual method was included and analyzed to provide a “do nothing” option for a system solution and was used to compare against the other system options.

The benefit, of using the manual process, is that nothing at SSC-A with respect to data calls will have to change. Data calls will continue as is, and no training will be needed for this effort. The flexibility of requesting data, that suits the requestors' needs, can easily be tailored during each data call cycle. Personnel have the freedom to use any tool with which they feel comfortable, excluding SSC-A mandatory tools such as NERP, Risk Exchange, or the Demand Signal Tool.

There are also disadvantages to using this method. Manual data calls take significant personnel time. Typically, data calls contain instructions on what type and when data is needed. This methodology was generally inconsistent, so the resulting data obtained from these data calls would be outdated and stale. The delay is caused by personnel being involved with higher priority items, taking annual / sick leave, and on travel.

Data collection is very troublesome when requesting information from personnel. This process requires personnel to capture and analyze required metrics manually. The cost for total man hours are increased due to the number of personnel involved in the process. Data storage of this information requires configuration management efforts from personnel which add to the costs. Displaying data trends manually requires time for personnel to manipulate the data into specific trends.

2. Automated Method

The automated method provides the capability instantaneously to collect data electronically using various SE Health Tools and software solutions. This method automates the collection of data to provide SSC-A's management up to date information on project system engineering health as described in the simulation section of this report.

B. ACQUISITION OPTIONS

The automated architecture could be implemented through three acquisition options described below: Automated Independent COTS Tools (All COTS), Automated Centralized (GOTS) System, and an Automated Hybrid Solution Set. The manual option is the current system in place, and will not require any acquisition.

1. Automated Independent COTS Tools (All COTS)

The Automated Independent COTS solution is defined as an automated process of collecting, storing, analyzing, and displaying the data using one complete or a set of existing commercial off the shelf solutions. The Automated Independent COTS option was identified to shorten development time and to leverage industry standards. This solution would inherently insert potentially challenging upgrades and licensing issues, as discussed clearly and in depth by Dr. David A. Cook in "*Issues to Consider before Acquiring COTS.*" However, having the mature technology available and being able to rapidly provide SE Health and Visualization indicators rapidly may be worth managing the risk.

The COTS tools and software upgrades would be maintained by the manufacturer. This would reduce the responsibility on the government for maintenance efforts with the exception of ensuring basic preventive maintenance practices.

The disadvantage of having an Automated Independent COTS solution would be that personnel are required to login to each one of the COTS tools to obtain the information desired by leadership. Manual processes may still have to take place to achieve the visualization of trends that leadership would want to analyze. There may be multiple software suites with little to no capabilities to display desired SELI visualization trends. Initially, the COTS tools would have to be procured and training of the tools would have to be coordinated; both would be front-loaded cost drivers. If the COTS tools are not all integrated by one manufacturer, there could be significant challenges to coordinate testing and approval prior to enabling the software to be automatically updated.

Data collection for Automated Independent COTS Tools would be possible for personnel to obtain information from a specific set of tools. This would also involve personnel having to gather and input the data; however, input of the data would be in various specified independent software suites. Analyzing this data would be easier since certain COTS tools are already mandated throughout the command. Therefore, having each of the related data fields automatically linked would reduce integration and analysis

delay challenges. The cost for this solution would include software, hosting environment, licenses, training, and man hours spent manually gathering data from tool suites. Data commitment would still require manual configuration management. Independent tool suites have the capability to display trends, but the integrated COTS combined display provides the capability to meet stakeholder visualization requirements.

2. Automated Centralized GOTS System

An automated centralized Government Off The Shelf system is defined as an automated process of collecting data using all software that is fully designed and developed "In-House." This type would require a plethora of programming and software design labor hours, as well as a suitable system maturity process that would allow for acceptable software modifications to occur as lessons are learned and requirements or system needs change. This option would require longer wait time for realization to provide results than any other option.

A benefit of having a GOTS System would include the ability to tailor the software to the exact needs of producing specific SELI trends. A web graphic user interface could be produced requesting planned data from the SE or SE Manager. That planned data could be compared with the actual data of the GOTS system that would pull from the SSC-A mandatory databases already in place. The planned versus actual data measures would show trends to determine overall project risk. Other benefits are the ability to rapidly direct work and change priorities without going through the contract process thus increasing the time for development. Quality Assurance, clean documentation, and control over the development of the product would prove advantageous for effectively saving cost. This proprietary in-house software would belong to SSC-A.

The disadvantages of the GOTS System include the time required for developing this in-house software and maintaining the software throughout the system's life cycle. Upgrades and updates of in-house software requires in-house personnel effort to perform the maintenance requirements. Subject Matter Experts (SME), for this tool, would have to be trained to provide the level of support required by users that may have trouble using

this type of system. Understanding that the advantages and disadvantages of GOTS could be costly, further study should be conducted using a cost-benefit analysis of this solution.

The data collection for the GOTS System would have to be tailored to support the required measures needed by leadership. Although, analyzing and capturing required metrics is possible with in-house developed software, developing a tool to capture, store, analyze and display will require a extraordinary degree of effort. Data commitment would be developed and tailored to the command's needs and displaying trends would need to be incorporated during development to show SELI trends.

3. Automated Hybrid Solution Set

A Hybrid System is defined as an automated process of collecting data using both COTS and GOTS software solution. The Hybrid System solution concept is the attempt to take the benefits of existing COTS Systems Engineering Tools and integrate them with In-House Tools. This option would help reduce time to provide a minimum visualization capability, but could then be modified to display specific visualizations. Inherently, this option would bring additional risks due to interface challenges that could occur as COTS are upgraded, compared to the other options.

The benefit of having a Hybrid System would include having middleware to integrate different tool suites, both COTS and GOTS. The Hybrid solution would have interoperability between the tools by harvesting the required data elements to produce visualization. The methodology of capture, store, analyze, and display would be used to effectively produce SELI trends. The concept of having SE / SE managers having the ability to use tools without being interrupted by data calls would be met. This solution would be the "middle man" to get the data elements from the tools that the SE / SE managers desire. This solution would also store these data elements without having personnel manually performing configuration management on historical artifacts. It would have the analytical features to perform basic calculations automatically for the visualization of this data. This would reduce the need for personnel manually performing these tasks as well as keep the integrity of the information. Up-to-date information would be the result of the Hybrid System. The disadvantage of the Hybrid solution includes an

upfront initial investment. Material and service procurement efforts have to take place to obtain the COTS tools as well as creating the Hybrid System.

The Hybrid solution would allow data collection to take place on command required tool suites. This provides little disruption to the SE / SE managers while data is gathered. Mandated tool suites for SSC-A and the use of developed software capturing, storing, analyzing, and displaying data would provide analytical data for the command performing SE activities. The initial cost would involve procurement of COTS software and the development of the "middleware" software.

C. ANALYTIC HIERARCHY PROCESS (AHP) EVALUATION CRITERIA

The architecture functions were evaluated within the AHP by analyzing the Assumptions, Constraints, and Safety and Security certification concerns identified in the below paragraphs for each system architecture.

1. Assumptions

The below assumptions were used when rating the architecture options during the AHP evaluation.

Manual Method

It was assumed that with the existing manual SE data input and display process, SE indicators were not available fast enough to prevent project failures or issues. It was also assumed and believed that this method took the longest time from data input to visualization. This was further evaluated in a modeling and simulation comparison with the automated option.

Automated Independent COTS Tools

It was assumed that for the All COTS solution not all desired SE data input or resulting SE health visualizations would be provided or even available. Further research would be required for each of the identified COTS tools to perform a thorough comparison of performance capabilities and limitations.

Automated Centralized GOTS System

It was assumed that the Automated GOTS solution would provide all initially identified capabilities. This solution would allow for SE data input into the interface method desired and required by the stakeholders, which would be a balance that often challenges the use of a system. It was also assumed that this solution would be modifiable by in-house support, and that training and help desk capabilities would be available as required.

It was further assumed that there could be an inherent loss of creativity, over time, with respect to generating a visual or even collecting SE data when choosing this system alternative. Without the feedback from industry on new developments, the current development and maintenance workforce would not see a need or even the possibility for improvement.

Automated Hybrid Solution Set

With the Hybrid System solution, it was assumed that the initial capability requirements would be met and the solution realized quickly. Although it likely required more time than with the All COTS solution, it was assumed multiple COTS product tools would be integrated with in-house developed tools to provide the data input, analysis, and visualization of SE leading health indicators.

2. Constraints

Each SEHV system architecture alternative has a different set of constraints that may impact their suitability to meet stakeholder requirements. For each of the options, specific constraints are identified as related to the system functions or other suitability criteria.

Manual Method

The existing manual process is constrained by current manpower availability. As SSC-A requests a change to an SE Process, the SE data input personnel require additional operational downtime to learn the new process and work out the new format of

information required for delivery. This often comes as a secondary requirement to the project effort itself, and therefore is not often implemented well. This labor constraint can cause schedule delays, reduced quality or cause incomplete products.

Automated Independent COTS Tools

The major constraint with the All COTS system solution was that upgrades occur when the vendor require thus making it impossible to maintain control over the environment. This allowed for interoperability challenges and training requirements depending on the magnitude of each applied change after the upgrade.

Automated Centralized GOTS System

Contrary to the All COTS constraints, this option would deploy upgrades, but would be able to do so only with SSC-A approval. With this control, there were still Safety and Security constraints that would force immediate upgrades to protect resources.

Automated Hybrid Solution Set

Similar to both the All COTS and in-house options, constraints on the Hybrid solution seem not to only have the sum of each individual option, but also included the integration constraints. As COTS upgrades occur, SSC-A would be forced to modify its in-house systems to continue to provide full functionality of the SEHV.

3. Safety and Security Certifications

Safety and Security Certification and/or Accreditation considerations play a large part of an IT system. Information Assurance (IA) requirements are identified in the DOD, based on the level of sensitivity of the data being stored or aggregated, to ensure data availability, authenticity, and other security best practices. Among the SEHV architecture options listed, the Manual Method is the only one that does not require direct IT Certification. However, depending on the implementation of each option, different safety and security concerns may apply to each.

Manual Method

Safety and Security measures for the existing manual process were already in place and being performed. Replacement of this method with one of the other three methods does not guarantee that those measures would still apply. Typically, each new option posed a new set of Safety and Security concerns to be evaluated.

Automated Independent COTS Tools

Safety concerns are addressed in the development of the COTS tools. Operational safety concerns would still need to be reviewed and evaluated.

Security certifications would be a challenge depending on the type of data the COTS allowed for storing or processing. If the data was sensitive to business operations, then special security concerns would need to be identified. Specifically, internal security measures should either allow or prevent SE project collaboration where more than one person could view or edit project data. However, there was a need to virtually host the systems behind network security layers or other types of IT security features approved prior to implementation and use. The most common government security requirement for a software system of these types would follow DOD information assurance requirements for Certification and Accreditation for use on a United States military network. Data commitment applications, SE tools, and visualization software would have to be approved and maintained to ensure the current software patches are being used. Vulnerabilities to software used in the SEHV solution would need to be updated and scanned on a consistent basis to satisfy IA security requirements.

Automated Centralized GOTS System

Safety and security considerations for this option would need to be reviewed for consistency with policy. They should be easier to comply with due to internal development, having access to the code and to the support personnel performing system modifications. This solution would cause a different level of safety and security concerns but they are expected to be resolvable faster than with the All COTS solution. This is due

to design, development, programming being performed internally, and allowing direct access to experts able to perform required modifications.

Automated Hybrid Solution Set

Security concerns for the Hybrid system option include coordination for the integration of COTS and an internal government self-development effort. COTS pieces would require their specific IA Accreditation as well as a separate certification of the GOTS components. Database software, SE / SE management tools, visualization software, as well as a graphic user interface (GUI) would have to be kept up to date with the latest IA security patches. Hosting environments would have to be scanned with IA tools to determine potential vulnerabilities and COTS and GOTS software would have to be evaluated by the SSC-A IA team to ensure there are no software security risks.

D. ANALYTIC HIERARCHY PROCESS

An AHP hierarchy is a structured means of modeling the decision at hand. It consists of an overall goal, a group of options or alternatives for reaching the goal, and a group of factors or criteria that relate the alternatives to the goal. It is a structured technique for organizing and analyzing complex decisions, based on mathematics, psychology and engineering judgment. It has particular application in group decision making (*Saaty 2008a*).

Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions (*Saaty 2008b*). The SEHV team used the AHP to evaluate four acquisition alternative ways of reaching the goal, and five criteria against which the alternatives need to be measured (after *Saaty 2008b*).

1. Overview

An evaluated selection process was conducted to determine the best analysis option to support the SEHV capability. The high level requirements stated that SSC-A required a system to provide SSC-A leadership with a tool to monitor SE program health in support of the warfighter. An AHP was performed to assist in making this determination. The following decision scenarios were considered in selecting the best acquisition option:

- SSC-A was in need of a solution for visibility into the SE health of its programs
- Acquisition procurement option had to be chosen for the SEHV capability
- Only two architecture options were available; Manual and Automated
- Choice would drive direction of SEHV system
- The team considered the following functions: Data Collection, Capture and Analyze Required Data Elements, Cost Effectiveness, Data Storage, and Data Trends Display

The SEHV team collected the acquisition options and the consideration criteria and conducted a pairwise comparison of alternatives with respect to each other. The priority vector of each criterion was calculated and then multiplied against each alternative to reach a solution. Figure 10 shows the SEHV solution strategy where supporting data and figures used to reach this decision are presented following this image.

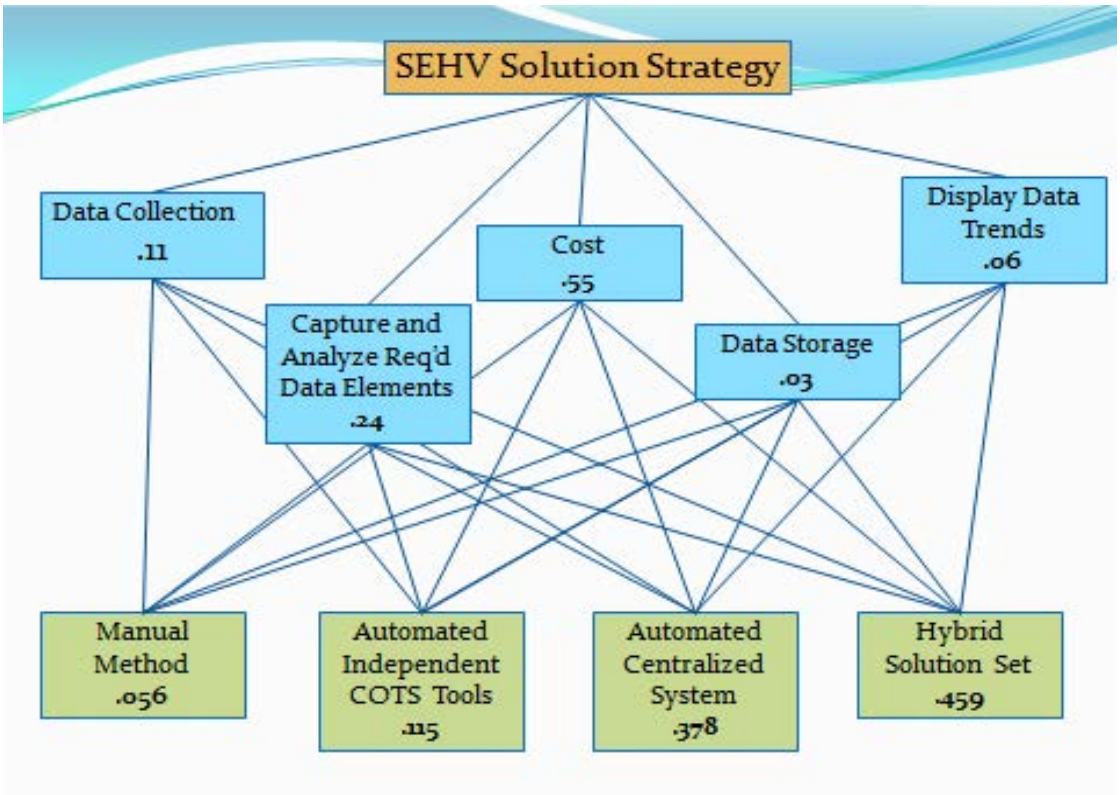


Figure 10. SEHV Analytic Hierarchical Process Diagram (after Green 2013)

2. Alternatives Comparison

Initially, a decomposition of decision criteria into comprehended sub-factors (i.e., data collection, capture and analyze required data elements, cost, data storage, and display data trends; each of which was analyzed independently) was performed (after *Saaty* 2008b). Utilizing engineering judgment, the team set levels of importance values from which to compare the criteria for fair competition. A pairwise comparison of the acquisition alternatives was performed to reach a formal conclusion of the best alternative for the SEHV solution strategy. Figure 11 displays the pairwise comparison matrix used for this project. The relative importance is shown with an associated importance value that aided in determining hierarchy of elements according to their importance comparatively.

Relative Importance	Value
Equal Importance/Quality	1
Somewhat More Important/Better	3
Definitely More Important/Better	5
Much More Important/Better	7
Very Much More Important/Better	9

Figure 11. Pairwise Comparison Matrix (from Green 2013)

Once the hierarchy was built, the team systematically evaluated the various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the team typically used their engineering judgments about the elements' relative meaning and importance. Using this pairwise comparison matrix as the foundation, a criteria comparison was performed to determine the priority vector of each element compared to one another. The hierarchy was constructed and analyzed through a series of pairwise comparisons that derived numerical scales of measurement. The criteria were pairwise compared against the goal for importance. The alternatives were pairwise compared against each of the criteria for preference. The comparisons were processed mathematically, and priorities (priority vectors) were derived for each (after *Saaty 2008b*). To show the element as less important to the competitor, the inverse was taken. Figure 12 displays the resulting outcome.

	Data Collection	Capture & Analyze	Cost	Data Storage	Data Trends Display
Data Collection	1	1/5	1/9	1	3
Capture & Analyze	5	1	1/7	7	9
Cost	9	7	1	9	7
Data Storage	1	1/7	1/9	1	1
Data Trends Display	1/3	1/9	1/7	1	1

Data Collection	Capture & Analyze	Cost	Data Storage	Data Trends Display
1	.20	.11	1	3
5	1	.14	7	9
9	7	1	9	7
1	.14	.11	1	1
.33	.11	.14	1	1
16.33	8.45	1.5	19	21

Data Collection	Capture & Analyze	Cost	Data Storage	Data Trends Display	Priority Vector
.06	.02	.07	.05	.14	**.07**
.31	.12	.09	.37	.43	**.26**
.55	.83	.66	.47	.33	**.57**
.06	.02	.07	.05	.05	**.05**
.02	.01	.09	.05	.05	**.04**

Figure 12. Criteria Comparison (after Green 2013)

To achieve the relative weight of a criterion or alternative, like probabilities, priorities are absolute numbers between zero and one, without units or dimensions. A criterion or alternative with priority .200 has twice the weight in reaching the goal as one with priority .100, ten times the weight of one with priority .020, and so forth. Depending on the problem at hand, "weight" can refer to importance, or preference, or likelihood, or whatever factor is being considered (after *Saaty 2008b*). The SEHV team refers to weight as preference for this capstone.

Priorities were distributed over the hierarchy according to its architecture, and their values depended on the information entered. Priorities of the Goal, the Criteria, and the Alternatives are intimately related, but needed to be considered separately. By definition, the priority of the Goal is 1.000. The priorities of the alternatives always add up to 1.000 (after *Saaty 2008b*). The SEHV team performed a comparison of acquisition options with respect to each alternative. Each comparison was concluded with the determination of a respective priority vector. Figures 13–17 provide supporting detail for the overall decision.

Data Collection	Manual Method	Automated Ind. COTS Tools	Automated Centralized System	Hybrid
Manual Method	1	1/3	1/5	1/9
Automated Ind. COTS Tools	3	1	1/7	1/7
Automated Centralized System	5	7	1	1/5
Hybrid	9	7	5	1

Data Collection	Manual Method	Automated Ind. COTS Tools	Automated Centralized System	Hybrid	P.V.
Manual Method	.06	.02	.03	.08	**.05**
Automated Ind. COTS Tools	.17	.07	.02	.10	**.09**
Automated Centralized System	.28	.46	.16	.14	**.26**
Hybrid	.50	.46	.79	.69	**.61**

Figure 13. Alternatives with Respect to Data Collection (after Green 2013)

Capture and Analyze Required Data Elements	Manual Method	Automated Independent COTS Tools	Automated Centralized System	Hybrid Solution
Manual Method	1	1/5	1/7	1/9
Automated Independent COTS Tools	5	1	1/3	1/7
Automated Centralized System	7	1/3	1	1/5
Hybrid Solution	9	7	5	1

Capture and Analyze Required Data Elements	Manual Method	Automated Independent COTS Tools	Automated Centralized System	Hybrid Solution	P.V.
Manual Method	.05	.02	.02	.10	**.05**
Automated Independent COTS Tools	.23	.12	.05	.23	**.16**
Automated Centralized System	.32	.04	.15	.14	**.16**
Hybrid Solution	.41	.82	.77	.69	**.67**

Figure 14. Alternatives with Respect to Capture and Analyze Required Data Elements (after Green 2013)

Cost Effectiveness	Manual Method	Automated Independent COTS Tools	Automated Centralized System	Hybrid Solution
Manual Method	1	1/3	1/5	1/9
Automated Independent COTS Tools	3	1	1/5	1/7
Automated Centralized System	5	5	1	5
Hybrid Solution	9	7	1/5	1

Cost Effectiveness	Manual Method	Automated Independent COTS Tools	Automated Centralized System	Hybrid Solution	P.V.
Manual Method	.05	.02	.13	.02	**.06**
Automated Independent COTS Tools	.17	.08	.13	.02	**.10**
Automated Centralized System	.28	.38	.63	.80	**.52**
Hybrid Solution	.50	.53	.13	.16	**.33**

Figure 15. Alternatives with Respect to Cost Effectiveness (after Green 2013)

Data Storage	Manual Method	Automated Independent COTS Tools	Automated Centralized System	Hybrid Solution
Manual Method	1	1/3	1/5	1/7
Automated Independent COTS Tools	3	1	1/3	1/5
Automated Centralized System	5	3	1	1/3
Hybrid Solution	7	5	3	1

Data Storage	Manual Method	Automated Independent COTS Tools	Automated Centralized System	Hybrid Solution	P.V.
Manual Method	.06	.04	.04	.08	**.06**
Automated Independent COTS Tools	.19	.11	.07	.12	**.12**
Automated Centralized System	.31	.32	.22	.20	**.26**
Hybrid Solution	.44	.54	.66	.60	**.56**

Figure 16. Alternatives with Respect to Data Storage (after Green 2013)

Data Trends Display	Manual Method	Automated Independent COTS Tools	Automated Centralized System	Hybrid Solution
Manual Method	1	1/5	1/7	1/7
Automated Independent COTS Tools	5	1	1/3	1/5
Automated Centralized System	7	3	1	1/3
Hybrid Solution	7	5	3	1

Data Trends Display	Manual Method	Automated Independent COTS Tools	Automated Centralized System	Hybrid Solution	P.V.
Manual Method	.05	.02	.03	.08	.05
Automated Independent COTS Tools	.25	.11	.07	.12	.14
Automated Centralized System	.35	.33	.22	.20	.28
Hybrid Solution	.35	.54	.67	.60	.54

Figure 17. Alternatives with Respect to Data Trends Display (after Green 2013)

3. Conclusion to Solution Strategy

For clarity, in this SEHV strategy, the goal is to select the best acquisition option; the criteria were the data collection, capture and analyze required data elements, cost, data storage, and display data trends capabilities; and the alternatives were the Manual Method, Automated COTS, Automated GOTS and Automated Hybrid options. To reach a determination of the best acquisition option for recommendation, a criterion versus goal comparison had to be completed. The total column value of each criteria element was divided into each element respectively. Figure 18 depicts where those values were then added (across row) to obtain the priority vector to be used to calculate the priority of each criterion alternative.

	Data Collection	Capture & Analyze	Cost	Data Storage	Data Trends Display
Data Collection	1	.20	.14	3	5
Capture & Analyze	5	1	.14	9	5
Cost	7	7	1	9	7
Data Storage	.33	.11	.11	1	.33
Data Trends Display	.20	.20	.14	3	1
Totals	13.53	8.51	1.53	25	18.33

	Data Collection	Capture & Analyze	Cost	Data Storage	Data Trends Display	P.V.
Data Collection	.07	.02	.09	.12	.27	**.11**
Capture & Analyze	.37	.12	.09	.36	.27	**.24**
Cost	.52	.82	.65	.36	.38	**.55**
Data Storage	.02	.01	.07	.04	.02	**.03**
Data Trends Display	.01	.02	.09	.12	.05	**.06**

Figure 18. Criteria versus Goal Comparison (after Green 2013)

Figure 18 displays the calculations that provide necessary information to determine the priority of each alternative with respect to criteria versus goal. Figure 19 shows the calculation matrix of each criterion hosting each alternative. The resulting answers were added together in a priority vector matrix, Figure 20, of criteria with respect to each acquisition option to conclude the final goal of the SEHV solution strategy.

Criterion	Priority vs Goal	Alternative	A	X	B	=	C
Data Collection	.11	Manual	.05	X	.11	=	.006
		Auto Ind. COTS	.09	X	.11	=	.010
		Auto Centralized	.26	X	.11	=	.029
		Hybrid	.61	X	.11	=	.067
							.11
Capture & Analyze	.24	Manual	.05	X	.24	=	.012
Req'd Data Elements		Auto Ind. COTS	.16	X	.24	=	.038
		Auto Centralized	.16	X	.24	=	.038
		Hybrid	.67	X	.24	=	.161
							.25
Cost	.55	Manual	.06	X	.55	=	.033
		Auto Ind. COTS	.10	X	.55	=	.055
		Auto Centralized	.52	X	.55	=	.286
		Hybrid	.33	X	.55	=	.182
							.56
Data Storage	.03	Manual	.06	X	.03	=	.002
		Auto Ind. COTS	.12	X	.03	=	.004
		Auto Centralized	.26	X	.03	=	.008
		Hybrid	.56	X	.03		.017
							..03
Data Trends Display	.06	Manual	.05	X	.06	=	.003
		Auto Ind. COTS	.14	X	.06	=	.008
		Auto Centralized	.28	X	.06	=	.017
		Hybrid	.54	X	.06	=	.032
							.06

Figure 19. Priority Relationship Calculation Matrix (after Green 2013)

	PRIORITY WITH RESPECT TO					
Competitor	Data Collection	Analyze & Capture	Cost	Data Storage	Data Trends Display	Goal
Manual Method	.006	.012	.033	.002	.003	**.056**
Automated Independen t COTS Tools	.010	.038	.055	.004	.008	**.115**
Automated Centralized System	.029	.038	.286	.008	.017	**.378**
Hybrid Solution	.067	.161	.182	.017	.032	**.459**

Figure 20. Criterion Priority with Respect to Acquisition Option (after Green 2013)

Based on the team's comparison, the Automated Hybrid Solution Set was the preferred alternative with a priority of .459. The Hybrid Solution Set was preferred over the other alternatives of the Automated Centralized System with a .378, then the Automated Independent COTS Tools with a .115, and finally the Manual Method with a .056, as seen in Figure 20.

IV. SELECTED SELI DETAILS

Five selected SELIs are detailed below and describe how SSC-A could tailor them for use with their current processes and systems. Each SELI discusses the associated processes, data collection procedures, data storage information, data analysis procedures, historical data information, and sample visualizations. Potential issues regarding implementation of these SELIs are also identified.

A. SELI 9, RISK EXPOSURE TRENDS

Described in INCOSE's SELI Guide version 2.0, the Risk Exposure Trends indicator depicts whether the project is effectively managing the project risks shown by predicted exposure ratings over time. Assessments can be made from trends that expose impacts to the project. This trend can illustrate whether a project is adequately managing exposed risks. The measurable concept includes having the capability to assess a project's effectiveness in managing and mitigating risks. This trend also promotes identifying risks that can severely impact the project's success. Managing the exposed risk can also be viewed when mitigation tasks are performed and referred to within the trend at a later date to see if the mitigation effort worked. This can indicate whether the mitigation of the risk was effective. If a particular mitigation is executed and resulted in extreme costs, this may indicate that another alternative may need to be considered if the risk were to appear again.

To properly use this trend effectively, a continuous risk management practice should be in place along with a repository that can store historical data. An active risk management habit will show potential risk for a project.

Risks related to the SEHV systems or applications were identified and documented based on the methodology in the INCOSE SELI 9 as well as NIST SP 800-30, Risk Management Guide for IT Systems. IT systems or application weaknesses were identified on an associated plan of action and milestones (POA&M) and tracked in accordance with SEHV POA&M guidelines. Appropriate protective measures were taken

to safeguard sensitive IT and SE system for application weaknesses or vulnerabilities from unauthorized disclosure.

1. Associated Process

Risk Exchange is currently being used at SSC-A, Charleston. SSC-A, New Orleans (NOLA), is currently using Excel spreadsheets. Table 3 depicts other tools that are in use to manage risk.

Table 3. Additional Risk Management Tools

Product	Company	Focus
CRAMM	Insight Consulting Ltd.	Government, Public Sector
CORA	International Security Technology INC	Telecom, Logistics, Government, IT
COBRA	C&A Systems Security Ltd.	Enterprise
Risk Check	Norman Security Solutions	Enterprise
Risk PAC	CSCI Inc.	Business Continuity
Risk Watch	Risk Watch Inc.	HIPAA, DITSCAP, NIACAP
The Buddy System	Alion Science & Technology	IT

2. Data Collection Procedure

Extracting high, medium, and low risks from the Risk Exchange tool is required to produce risk exposure trends. Obtaining risk data on a monthly basis will ensure up to date trends are produced. A historical database is needed to show these trends over time. Table 4 displays the data collection procedure used for risk exposure.

Table 4. Risk Exposure Data Collection Procedure

Base Measure	**Data Collection Procedure**
Frequency of Data Collection	Monthly
Responsible Individual	Project Manager
Activity in which collected	Extracting high, medium, and low risks from the Risk Exchange tool
Potential Sources of Data	Risk Exchange
Typical Tools used in Data Collection	Online GUI
Verification and Validation	Reviewed Monthly
Repository for Collected Data	Suggested: Historical Database

3. Data Storage

Current risk data is stored in Risk Exchange and other risk tools. Depending on the SSC-A accepted risk data collection frequency, risk data should be pulled from Risk Exchange, time stamped, and stored in the SEHV historical database.

Table 5, which provides data elements, is suggested for collecting and storing Risk Exposure data.

Table 5. Risk Data Elements

Inputs/Outputs (Data Elements) Required	**Tool or Data Sources**	**Metric/Formula used With**
List of Portfolio Names for Risk Exchange	Risk Exchange	% of Portfolio's using Risk Tool
List of Project Names for Risk Exchange	Risk Exchange	% of Projects using Risk Tool
Count of CURRENT Risks LOW Criticality to Cost/Schedule/ Performance, per Project, per Portfolio	Risk Exchange	Low Risk Trends
Count of CURRENT Risks MEDIUM Criticality to Cost/ Schedule/Performance, per Project, per Portfolio	Risk Exchange	Medium Risk Trends
Count of CURRENT Risks HIGH Criticality to Cost/Schedule/ Performance, per Project, per Portfolio	Risk Exchange	High Risk Trends
Count of PREVIOUS Risks LOW Criticality to Cost/Schedule/ Performance, per Project, per Portfolio	SEHV Analysis and Visualization Server	Low Risk Trends
Count of PREVIOUS Risks MEDIUM Criticality to Cost/ Schedule/Performance, per Project, per Portfolio	SEHV Analysis and Visualization Server	Medium Risk Trends
Count of PREVIOUS Risks HIGH Criticality to Cost/Schedule/ Performance, per Project, per Portfolio	SEHV Analysis and Visualization Server	High Risk Trends

4. Data Analysis Procedure

SEHV stored risk data will consist of the Low, Medium, and High risks per project. Analysis of these risks will initially involve only the high level counts of each, to be graphed with the current counts, which should enable the visualization of increasing or decreasing trends in Risk Exposure. Table 6 displays the data analysis procedure with respect to risk exposure.

Table 6. Risk Exposure Data Analysis Procedure

Indicator	**Process Compliance Trends**
Frequency of Data Reporting	As requested by authorized personnel
Responsible Individual(s)	Project Manager, IPT Lead Code 01B Director of Management Operations Code 011 Inspector General Business Portfolio Business Portfolio Management (BPM) Deputy Portfolio Manager (DPM) SubPortfolio Lead (SPL) Integrated Product Team (IPT) Lead IPT Technical Lead Integrated Product Team Project Manager
Activity which Analyzed	Observing Risk trends and mitigation efforts
Source of Data for Analysis	Risk Exchange
Tools Used in Analysis	Risk Exchange
Review, Report, or User	Review

5. Historical Data

Many programs have historical risk data that may or may not be easily comparable to the SEHV suggested Risk Exposure trend data. The SEHV database would need to store newly collected Risk data elements from Risk Exchange or other risk tools, on either weekly basis or other SSC-A approved frequency. This data would then be time stamped and used as historical data for display and comparison against current data as requested by SSC-A stakeholders to view SE Risk leading indication of project health.

6. Sample Visualizations

Figure 21 displays Risk Exposure Trends in low, medium and high priority risks over time with respect to cost and schedule. A steady decline of risks would indicate a project was performing risk management practices. Leadership and stakeholders of a project would discuss these trends during regularly scheduled reviews.

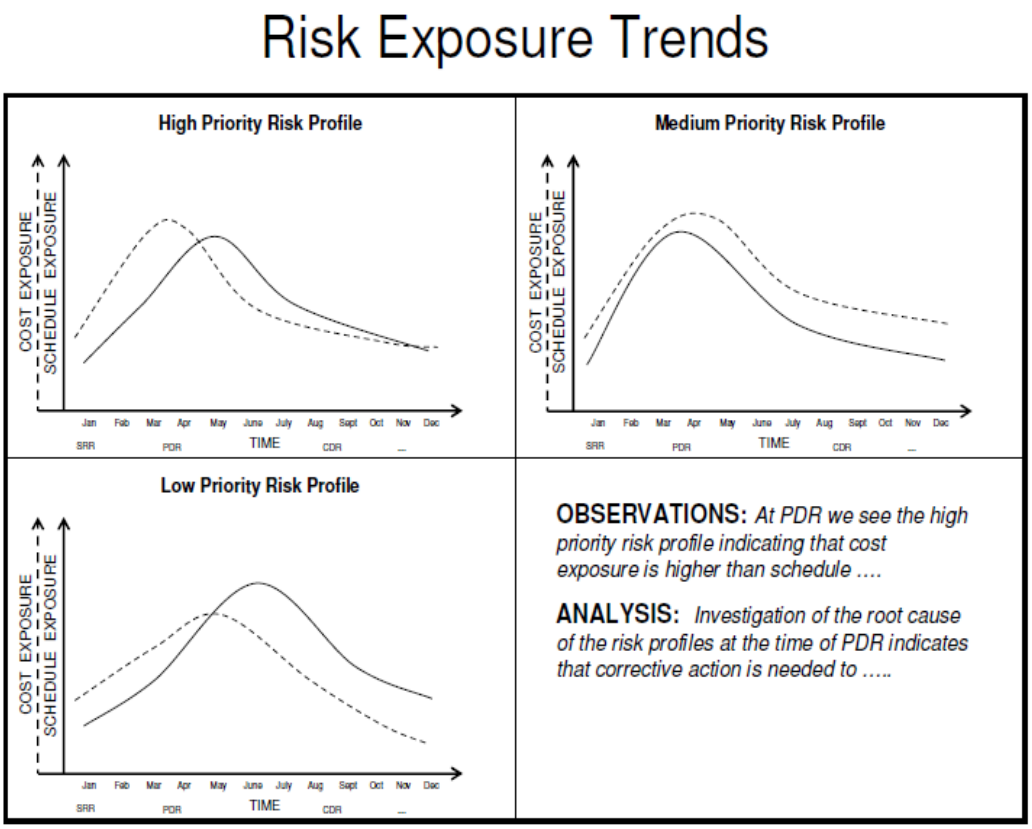


Figure 21. Risk Exposure Trends (from INCOSE et al. 2010)

B. SELI 11 , SE STAFFING AND SKILLS TRENDS

SE Staffing and Skills Trends are used to see how many SE activities are being performed on a project. The amount of SE activities will dictate the number of personnel or needed personnel for a project. To adequately keep a project going, especially for a large Acquisition Category I (ACAT1) program, continuous SE activities are needed and required. SSC-A has identified continuous management functions such as risk management, requirements management, interface management, configuration management, technical data management, technical assessment, decision analysis, service management, product support management, quality management, lessons learned management, business resource & financial management, contract management, science and technology management, and human resource management that must be conducted throughout the life cycle of the project.

The SE Staffing and Skills Trends SELI would be used to identify if the project has the right manpower resources to accomplish project objectives. The need for this type of trend at SSC-A is critical to determine if the amount of SE a project needs aligns with the personnel resources on that project. Personnel volatility can also indicate a potential risk of cost overruns, and schedule slippages. New SE personnel always undergo a learning curve where understanding the project, and knowing who are the key players takes time. Personnel retention is favorable if the project is performing well and the job is being completed. High personnel turnover can also indicate that there may be a much larger invisible problem on the project. A project with unrealistic goals, continuous punishable repercussions on team members by management, hostile work environment and other negative project traits can lead to team members leaving the project.

These trends can also display if a project is even performing certain SE efforts. The lack of performing critical SE functions can give a strong indication of project failure, especially when a project is not doing well to begin with. When a project is not doing well, an aspect to consider is if the team members of the IPT have the appropriate knowledge, skills, and abilities (KSAs) to perform SE tasks. Training can help mitigate some of these KSA deficiencies; however each person has a learning ability that may be greater than or less than the next person.

The leading insight provided for this SELI would illustrate a right balance of SE staffing for successful projects versus unbalanced SE staffing for a struggling project. Although SSC-A currently does not track this type of measure, the sooner this SELI is being utilized and tracked, the sooner historical data can be created to display such trends. SSC-A does have a Competency Development Model (CDM) for personnel; however soon after the practice was performed, the CDM data gathering stopped. This effort will need to be rekindled to depict the skill levels of personnel especially with SE efforts. SE Staffing and Skill Trends display gaps and / or shortfalls of SE effort with respect to IPT members KSAs. Poor project outcomes can result from inadequate SE staffing and skillsets.

Planned SE efforts vs actual SE efforts can be measured to display trends over time. If the planned SE efforts outweigh the actual SE efforts for a troubled project, perhaps either there is not enough manpower within the organization or SE / SE management practices are not being considered as important. Since different amounts of SE efforts are considered during each phase of the project life cycle, planned SE effort projections are needed to provide early indication that insufficient personnel risks inadequate performance of SE practices. Unit of measures for this particular SE can be portrayed as SE man-hours associated with the type of SE process. Planned values of SE man-hours can enforce the need of either fulltime staff to perform SE daily or part-time staff that perform these functions a number of hours throughout the week as a collateral duty. Figure 22 displays a visual depiction of this concept.

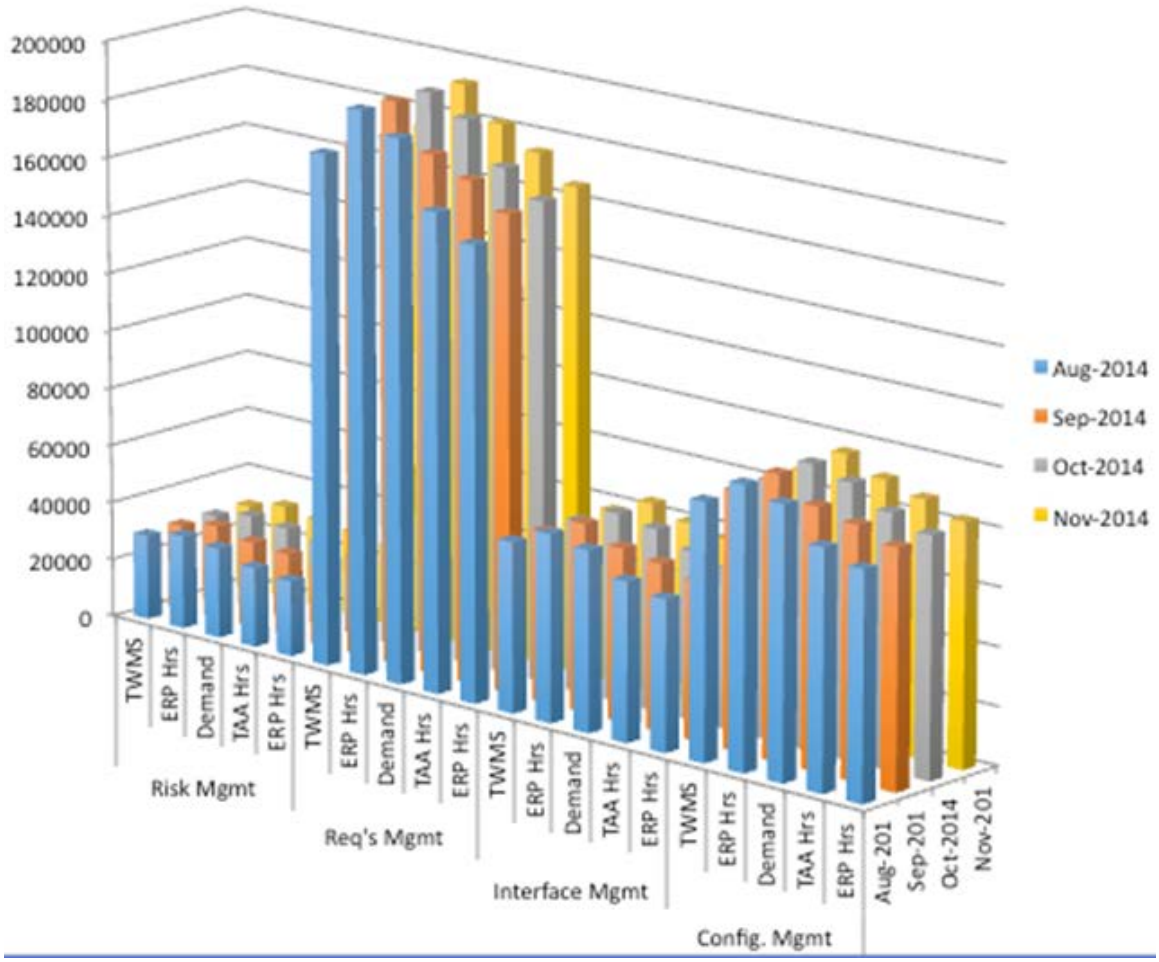


Figure 22. Planned SE Effort versus Actual SE Effort

SE activities can fluctuate throughout the project life cycle. An example would include volatile or unclear requirements during the planning phases which numerous man-hours for SE requirements management is needed vice when the project is within the production and deployment phase of the project life cycle. Another example would include risk management being a critical need for a struggling project during a period of time when a plethora of high risks are realized vice another period of time of only having minimally low and medium risks.

Measurement methods for this SELI include SE effort hours for individual SE process areas with respect to time. Counting the planned effort hours and comparing with the actual effort hours spent on SE will show possible deficiencies in any particular SE activity on a project. An array of data involving the planned vs. actual SE man-hours is

used to display the trends in the form of bar graphs. SE / SE management will input the planned values for each SE process area at least monthly to keep an updated SE effort profile on a project. Failure to do so should involve leadership intervention to mitigate SE management shortfalls within a project.

NERP has Global Work Breakdown Structure (GWBS) elements assigned to Network Activities (NWAs) to which government personnel charge their time. These GWBS elements specify SE activities such as Studies & Design, Architecture, Human Systems Integration (HSI), Technical Authority, Certification Authority, Systems, Engineering Management, Requirements Analysis, Configuration Management, and Logistics Engineering. Although not all SE efforts are listed under the GWBS, additional SE activities could be added to the GWBS or rolled up into other labeled criteria.

SE / SE management staffing needs, actual available personnel, and total workforce trends can reveal how much emphasis SSC-A has on SE / SE management staffing and skills. Information such as the length of time a SE / SE management is needed for a project can determine availability of personnel at a given point in time. This measure could also illustrate when projects come to an end, an actual surplus of personnel within the SE field. Having a well-balanced workforce is essential for the success of a project, program, command, or any Government / Military organization. Tools such as the Demand Signal Tool and Total Workforce Management System (TWMS) should be used to obtain the appropriate data to display these trends.

SSC-A has a staffing tool (Demand Signal Tool) that is used to determine a project's needs in regards to manpower. The Demand Signal Tool allows projects to submit their needs for staffing. This tool can provide data that shows how many resources the command needs with respect to a particular position. Common needs throughout projects can reveal a deficiency for a particular type of work within the command. If the need is high enough, hiring action should be considered to fill in the gaps where SE / SE management is critically needed. Exporting this data to an Excel spreadsheet is a feature of the Demand Signal Tool. Data can be filtered into different areas of interest once the data is exported. Extracting this data from the Demand Signal Tool can provide valuable information to the SEHV system. Information such as the amount of SE / SE

management personnel the command needs by IPT, portfolio, competency, and sub-portfolio. This data, for needed personnel, would be updated to reflect the status of the Demand Signal itself. This updated data would fuel the SEHV system for visualization display to the command.

TWMS is used to include skillsets, education, training, experience, pay bands, military / veteran information, and position. Within SSC-A's Competency Aligned Organization (CAO), personnel are aligned within competencies associated with the type of work that is being performed. This type of methodology would include knowing what competency to choose for a particular type of work. For instance, the 5.2 competency is primarily for SE / Industrial Engineering. The 6.3 competency is strictly for program management. The 4.3 competency is labeled as the logistics competency. Aligning similar skillsets to a specific group is a good way to organize personnel. Unfortunately, this methodology restricts personnel to performing only the advertised competencies and responsibilities. Although personnel may have the expertise and capabilities to perform multiple functions, that same personnel is limited on what they can or cannot do when placed in a specific competency. A person with multiple capabilities such as SE management and logistics assigned to the 4.3 competency would be limited to performing logistics functions rather than performing both SE management and logistics tasks. The organization should include primary, secondary, and even other skillsets that personnel may have in order to economically provide the right expertise for the right type of work demanded needed. This data would be extracted to depict trends relating to staffing and particular skill sets. These KSAs could be displayed as bar graphs for the amount of available personnel with specific skill sets or even reveal a deficiency in a particular skill group. These data elements should be compared with the Demand Signal Tool information on the number of needed SE / SE management resources.

SE Staffing and Skill Trends display a project's effort in regards to SE. Planned values should be reviewed monthly by the IPT Lead. If actual SE hours are not meeting the planned or expected amounts of SE required, this could allow leadership to intervene to promote the execution of needed SE activities. Another way of using SE Staffing and Skill Trends would be to show how many SE / SE management personnel are needed in

an organization compared to the actual SE / SE management personnel available. A high demand of personnel could trigger the Tier 3 Competency Manager to begin the hiring action process. The IPT lead could also use this SELI trend to pick up available personnel for their IPT.

1. Associated Process

The NERP, TWMS, and Demand Signal tools are used to capture data for this SELI. The data is captured real time and the information would be evaluated monthly, and as needed when the information is being requested.

2. Data Collection Procedure

Extracting data from NERP, TWMS, and the Demand Signal Tool is required to produce SELI trends. Obtaining SE staffing and skills data on a monthly basis will ensure up to date trends are produced. A historical database is needed to show these trends over time. Table 7 displays the data collection procedure for SE staffing and skills.

Table 7. SE Staffing and Skills Data Collection Procedure

Base Measure	**Data Collection Procedure**
Frequency of Data Collection	Monthly
Responsible Individual(s)	Project Manager, IPT Lead
Activity in which collected	SE Planned vs SE Actual (Performed on a Project) Manpower Needs vs Available
Potential Sources of Data	NERP, TWMS, Demand Signal Tool
Typical Tools used in Data Collection	Excel
Verification and Validation	Reviewed Monthly
Repository for Collected Data	Suggested: Historical Database

3. Data Storage

SE Staffing and Skills trend data should be stored in a historical database. This historical data can be pulled and compared to actual current data from each of the tools used within SSC-A. Most SSC-A projects use the same tools to store their project staffing requirements and actual usage or effort spent on the project over time. An interface will need to be able to collect the actual effort data from each tool, per skill, per project, and per portfolio at the frequency interval determined, and store within the historical database. Table 8 is suggested for collecting and storing SE Staffing and Skills data.

Table 8. Staffing and Skills Data Elements

Inputs/Outputs (Data Elements) Required	**Tool or Data Sources**	**Metric/Formula used With**
List of Portfolio Names for SE Staffing & Skills Trends	NERP	% of Portfolio's using SE Staffing & Skills Tool
List of Project Names for SE Staffing & Skills Trends	NERP	% of Projects using SE Staffing & Skills Tool
List of Skill Areas per Project, Per Portfolio	NERP	Compare to Standard SE Template Required for that IPT or Project Type
CURRENT SE Effort PLANNED in hours, per skill, per project, per portfolio	NERP	SE Effort per Project Trend
CURRENT SE Effort ACTUAL in hours, per skill, per project, per portfolio	NERP	SE Effort per Project Trend
CURRENT SE Effort AVAILABLE in hours, per skill, per project, per portfolio	TWMS	SE Effort AVAILABLE minus PLANNED equals SSC-A Overhead Surplus Effort
CURRENT SE Effort REQUESTED in hours, per skill, per project, per portfolio	Demand Signal Tool	SE Effort REQUESTED minus OBLIGATED equals Effort Unfilled but Available
CURRENT SE Effort OBLIGATED	TAA Tool	SE Effort OBLIGATED minus

in hours, per skill, per project, per portfolio		ACTUAL equals Effort Project Gap Unplanned
PREVIOUS SE Effort PLANNED in hours, per skill, per project, per portfolio	SEHV Analysis and Visualization Server	SE Effort per Project Trend
PREVIOUS SE Effort ACTUAL in hours, per skill, per project, per portfolio	SEHV Analysis and Visualization Server	SE Effort per Project Trend
PREVIOUS SE Effort AVAILABLE in hours, per skill, per project, per portfolio	SEHV Analysis and Visualization Server	SE Effort AVAILABLE minus PLANNED equals SSC-A Overhead Surplus Effort
PREVIOUS SE Effort REQUESTED in hours, per skill, per project, per portfolio	SEHV Analysis and Visualization Server	SE Effort REQUESTED minus OBLIGATED equals Effort Unfilled but Available
PREVIOUS SE Effort OBLIGATED in hours, per skill, per project, per portfolio	SEHV Analysis and Visualization Server	SE Effort OBLIGATED minus ACTUAL equals Effort Project Gap Unplanned

4. Data Analysis Procedure

Data analysis should be performed monthly to ensure planned versus actual values are within a close range. Actual values indicating inadequate man-hours spent on SE activities over a period of time would indicate potential risk of project not having enough personnel to fulfill SSC-A SE project requirements. Intervention is recommended when actual values decrease from what was originally planned over a period of time. Table 9 displays the data analysis procedure for SE staffing and skills.

Table 9. SE Staffing and Skill Data Analysis Procedure

Indicator	**SE Staffing and Skill Trends**
Frequency of Data Reporting	Monthly
Responsible Individual(s)	Business Portfolio Manager (BPM) SubPortfolio Lead (SPL) Integrated Product Team (IPT) Lead IPT Technical Lead Tier 2 Competency Lead (CL) Tier 3 Competency Manager (CM) Tier 4 Competency Supervisor First-Line Supervisor Contracting Officer's Representative (COR) Integrated Product Team
Activity which Analyzed	Determining the amount of SE being performed in terms of man hours. Comparing the Supply & Demand of SE / SE Management Personnel
Source of Data for Analysis	NERP, TWMS, Demand Signal Tool, TAA
Tools Used in Analysis	NERP, TWMS, Demand Signal Tool, TAA
Review, Report, or User	Review

5. Historical Data

Historical SE Staffing and Skills Effort data will be stored in the SEHV database. Data elements from NERP such as hours charged for SE efforts will be used to determine planned versus actual values. TWMS would provide the number of total personnel with specific skills and specialties over time. The number of needed personnel with specific skills and specialties would be gathered from the Demand Signal Tool. The TAA application would offer data such as personnel with obligated commitments to specific project as well as potential availability times. These historical values would produce trends for planned versus actual values in regards to SE staffing and skills.

6. Sample Visualizations

SE Staffing and Skill Trends display SE activities performed over time with respect to hours of SE effort. Continuous SE throughout the project lifecycle would indicate adequate SE practices were being performed. Leadership and stakeholders of a project would discuss these trends during regularly scheduled reviews. Figure 23 displays a notional view of trends for SE staffing.

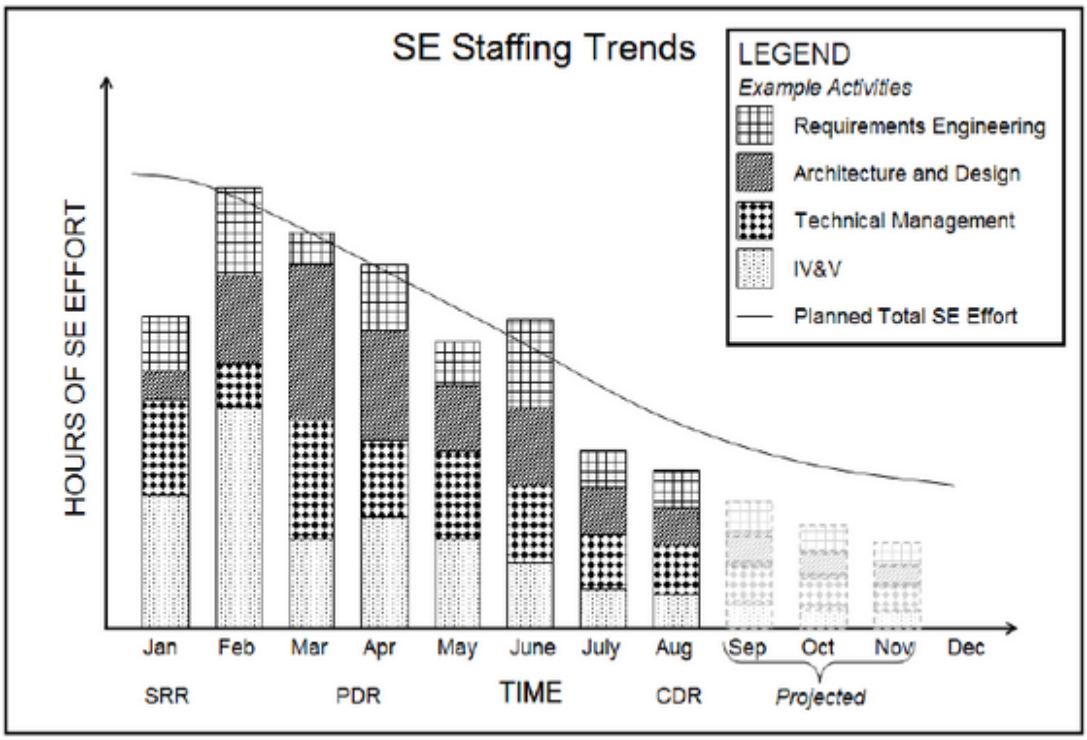


Figure 23. SE Staff and Skill Trends (from INCOSE et al. 2010)

C. SELI 12 PROCESS COMPLIANCE TRENDS

Process Compliance Trends are used to measure risks of ongoing process performance, potential increases in variance, risk to downstream processes, and risks to the outcome of the project (after Roedler 2005). As an organization identifies and documents its processes, each action is typically included due to its performance of a valuable and measurable function output. If the process actions are not completed in proper or are neglected completely in performance of the process, then it can be an indication that the quality of the overall process and its outputs may not be as desired. This reduction of quality can be quantified as a performance risk, which could also translate to schedule and cost risks if the resulting products are degraded to the point of requiring re-work. Process actions completed out of order or not completed as required can be combined and be measured as a general metric covering process discrepancies. Measuring process compliance is not the same as measuring process effectiveness. It is expected that automating this SELI will be very challenging due to auditing process artifacts for compliance and due to the variety of process types within SSC-A.

Process implementation is the basic requirement necessary before data can be collected to show process compliance trends. Industry standards, such as the International Organization of Standards (ISO) 9000, identify a process approach as a quality management function to be adopted within an effective organization. ISO 9000 identifies monitoring and measuring the processes and product against requirements and objectives, as well as using the results to continuously improve the processes (ISO 2012).

Another model, such as Capability Maturity Model Integration (CMMI), identified a rating method for an organization's process maturity. Measuring the maturity of processes helps to ensure continued process improvement. This type of measuring is not a type of measuring for process compliance but could still be used to show an indication of SE health (CMMI Institute 2014).

SSC-A manages engineering programs and projects using processes in various phases of process maturity. Some of the programs have long term customer commitment where value is clearly visible for the investment cost of documenting the processes

required and managing the compliance discrepancies. Other programs have such unique, short-lived functions, that the only documented and repeatable processes are those related to the SSC-A business functions. Figure 24 displays the SSC-A business processes which are in the construction phase following the guide of the SPAWAR Atlantic Joint Framework.

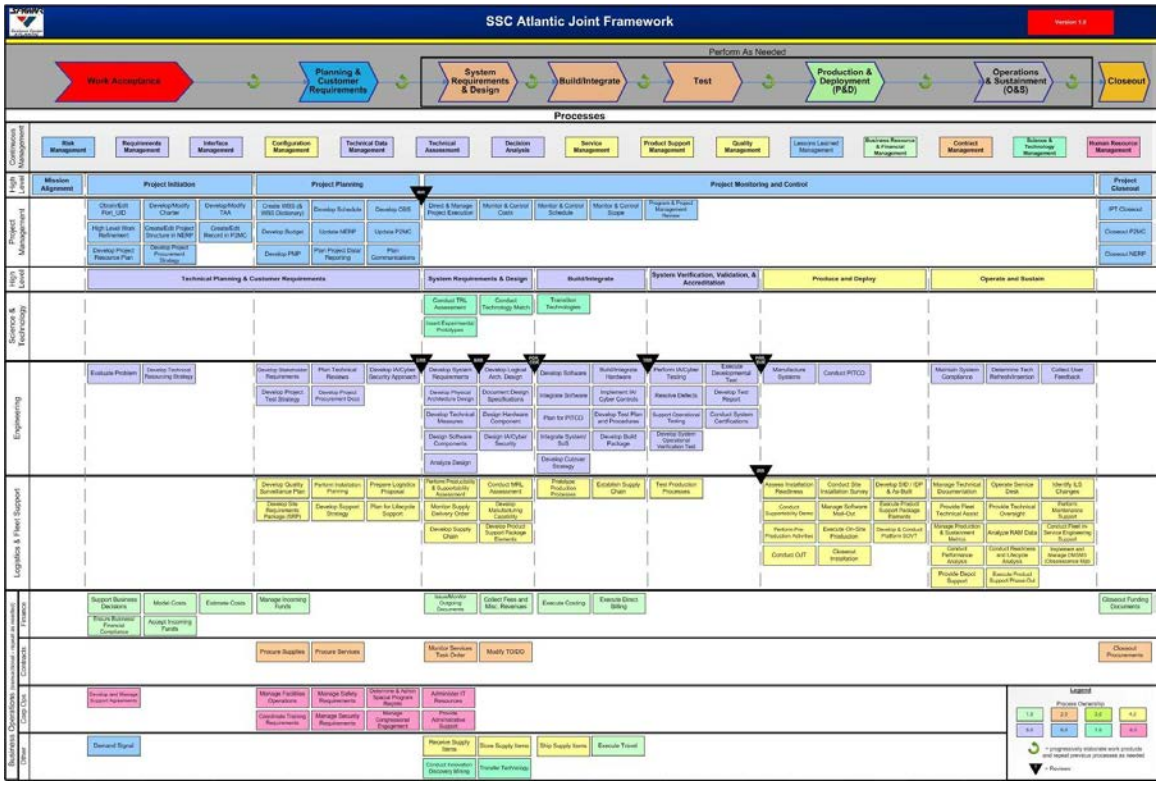


Figure 24. SSC-A Joint Framework (from SPAWAR Atlantic 2014)

The intent of this framework is to show all of the business processes, to include engineering functions, as a guide to performing work for SSC-A customers. Currently, a majority of the high level processes are documented, but all of them are under Continuous Process Improvement (CPI). Some of these processes are being delivered more like a procedure, which is a difficult challenge that continues to need to be worked out as specific process requirements no longer work for all cases.

SSC-A has already documented a procedure for how to review process compliance. This is a procedure that falls under the validation phase of their Process

Management process. Figure 25 is a diagram showing the SSC-A Process Management process and the validation phase Process Compliance procedure.

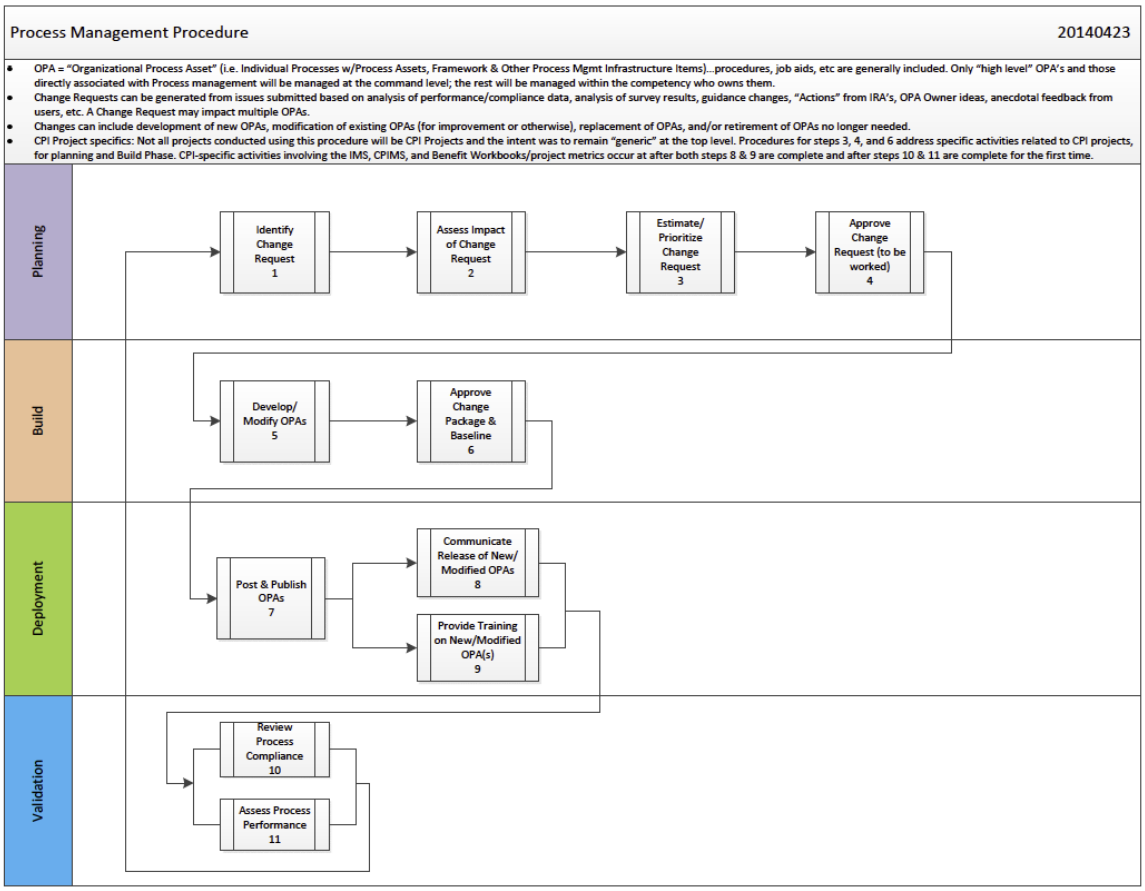


Figure 25. Process Management Procedure Diagram (from SPAWAR Atlantic CPI ESG 2014)

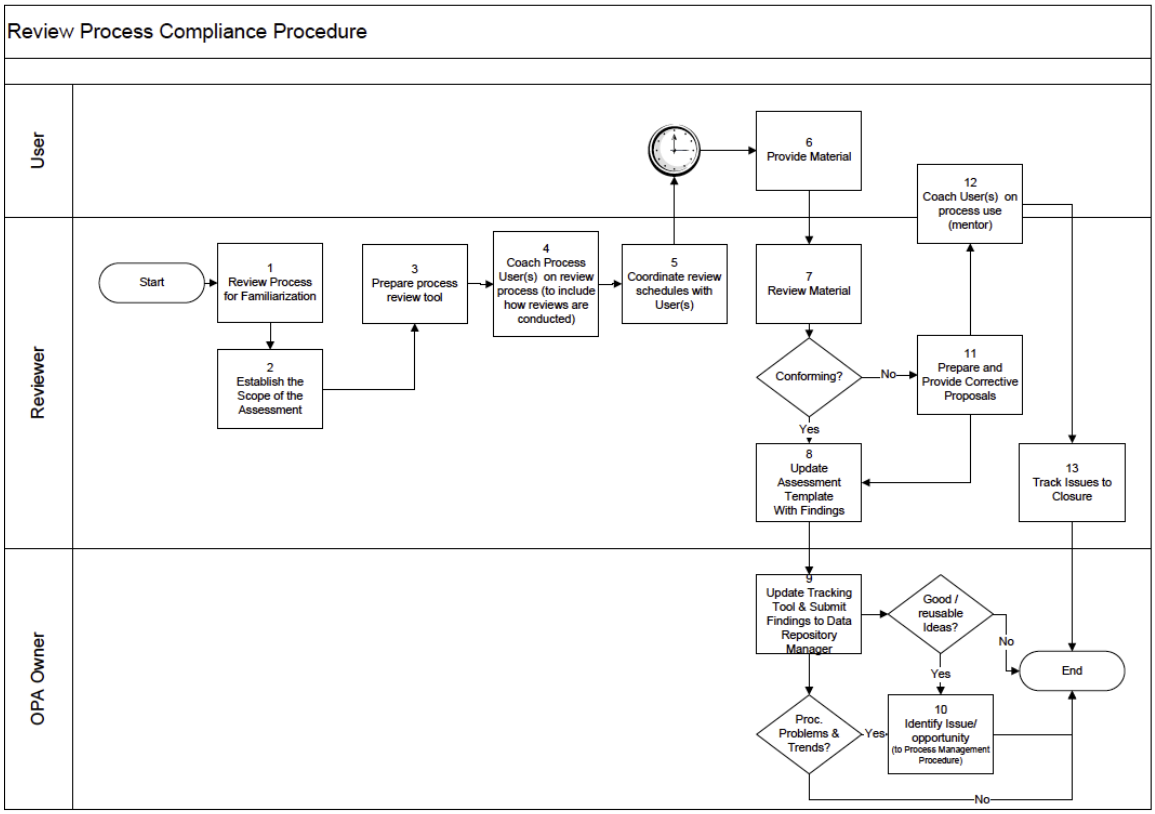


Figure 26. Process Compliance Procedure Diagram (from SPAWAR Atlantic CPI ESG 2014)

When validating a program or project process, SSC-A shows in steps 7 and 8 of Figure 26, the check that the artifact material provided, conforms to the requirement. This validation check allows for SSC-A to track the quality of valid process artifacts but not specifically process compliance. This type of validation seems to work best for the command due to the numerous variations between program and projects, customers and sponsors, and industry partners utilized when performing engineering services and support. Each project team can provide an acceptable product regardless of the exact steps followed within the process. If SSC-A were to build their process compliance procedure to capture process variation, then they would also need to measure the variation within each IPT to have a more accurate view of program or project risk due to inconsistent process compliance.

Customers or sponsors desiring to do business with SSC-A may also be interested in process compliance trends. If they could also see that the products and services being provided were following documented processes and then be able to regularly view an updated status of compliance to the applicable processes to their support project, then it may increase the reliability they place on SSC-A performance capabilities.

1. Associated Process

There are two common variations of process compliance trend measures that an organization like SSC-A could use as well as many other individual cases such as the one currently possible with the existing SSC-A process compliance validation procedure. Each of these use cases would require measuring different data inputs, some requiring more or less data than the other, and some having automated tools available to help rapidly obtain and measure.

The first case identified by industry in the SELI guide, is to count the number of discrepancies per process required to be followed, and then arrange them in a pareto chart showing the highest to lowest discrepancies. This is a chart displaying ordered quantities from highest to lowest in each category. Figure 27 is an example of this type of graphical representation from the SELI guide.

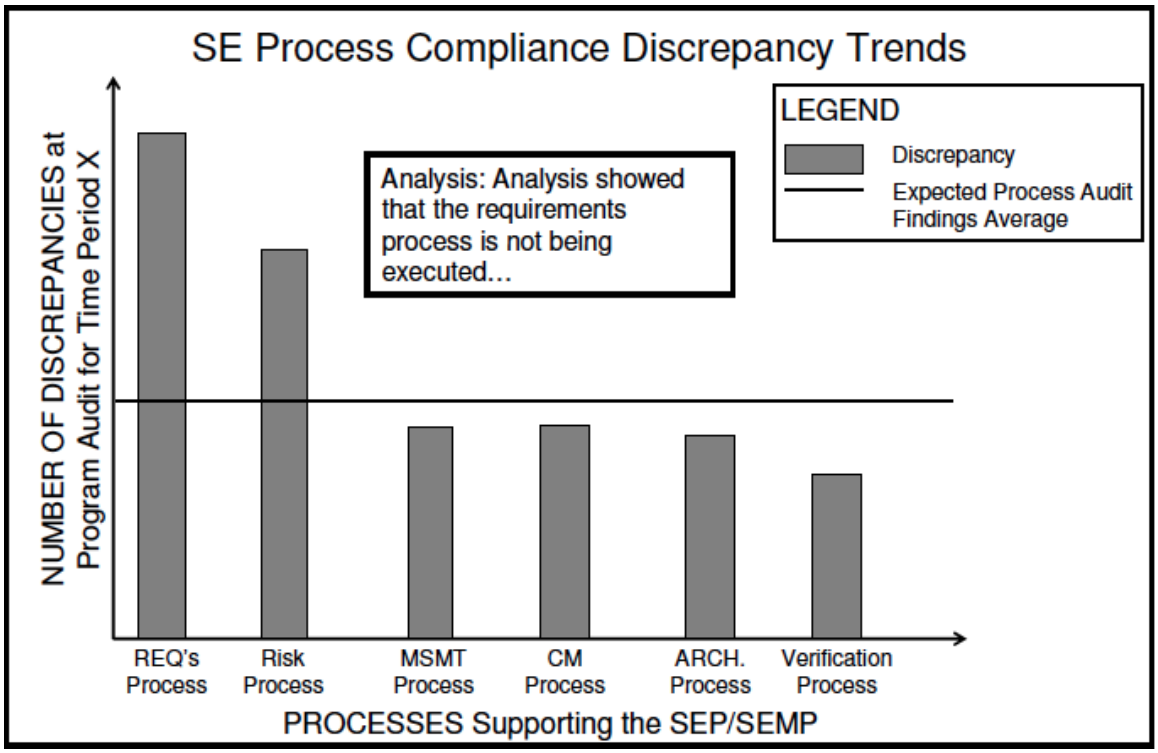


Figure 27. SE Process Compliance Discrepancy Trends (from INCOSE et al. 2010)

The next more detailed use case also identified by the SELI Guide is to arrange and graph the identified process discrepancies by the type or by cause of the process compliance discrepancy. In this case, it would require the collection of process attributes such as process type or discrepancy cause. Figure 28 depicts the SELI Guide example of this type of visualization. The number of discrepancies found is shown on the Y axis, and the different processes within each process area are listed on the X axis.

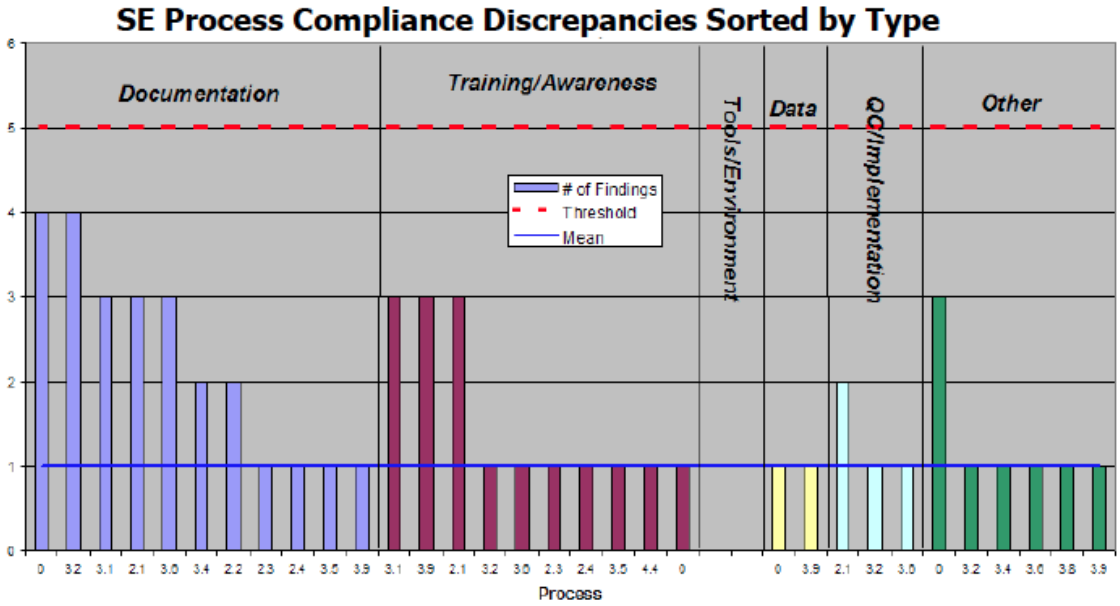


Figure 28. SE Process Compliance Discrepancy Diagram

Other variations of use cases would include varying the process attribute data collected. Some of the attributes helpful to examine for use are quantity of artifacts produced, risk or importance of process accuracy, frequency of process use, and time to complete process from beginning to end. In the case of SSC-A, as previously shown, they will collect the quantity of artifacts produced.

Tools available for use in measuring process compliance are often limited to the tools used to document processes. Configuration Management Professional (CMPro) and Atlassian JIRA are two of the known current tools that SSC-A uses to track process compliance. On many smaller projects, Excel has been used to list the process steps in one column, and then identify a date next to each step when it is completed, or type a comment on why it could not be completed if necessary. This method of process management is difficult to collect among multiple different projects due to usage of different Excel Templates, and minor variations within each IPT's use of a template that may have been provided.

Data capture from these tools or process audits can occur as often as at the completion of every process, or as random as when the next auditing person has time. However, industry advice suggests that an organization audit those processes which are

most important to success or performed the most often during an identified period of time. At SSC-A, a majority of periods of time are based on project schedules, also there is very little historical knowledge on process audits since the documented processes are still very new and some have not even been documented. Once a process has been documented and training provided to users of the process, then it would seem beneficial to audit at least one process compliance event per IPT per process area, per funding Period of Performance (POP). If the effort is not automated, then it would cost a considerable amount of labor in the beginning compared to further in the maturity of the organizations use and modification of the processes.

2. Data Collection Procedure

Extracting data from CMPro and Atlassian JIRA is required to produce SELI trends. Obtaining process compliance data on a monthly basis will ensure up to date trends are produced. A historical database is needed to show these trends over time. Table 10 displays the data collection procedure for process compliance.

Table 10. Process Compliance Data Collection Procedure

Base Measure	**Data Collection Procedure**
Frequency of Data Collection	Varies by process maturity, suggested initially: Once per process area, per Period of Performance per project.
Responsible Individual(s)	Chief Systems Engineer, Process Lead, Quality Assurance Manager
Activity in which collected	All applicable SE Phases
Potential Sources of Data	CMPro, Atlassian JIRA
Typical Tools used in Data Collection	CMPro, Atlassian JIRA
Verification and Validation	Process outcome product quality conformance
Repository for Collected Data	Suggested: Historical Process Compliance Database

3. Data Storage

Process compliance trend data should be stored in a historical database. This historical data can be pulled and compared to actual current data from a process tool used within SSC-A. Since many SSC-A projects use different tools to store their process requirements, an interface will need to be able to collect the actual compliance status per process, per project, and per portfolio at the frequency interval determined, and store within the historical database.

Table 11 displays data elements that are suggested for collecting and storing process compliance data.

Table 11. Process Compliance Data Elements

Inputs/Outputs (Data Elements) Required	**Tool or Data Sources**	**Metric/Formula used With**
List of Portfolio Names for Process Compliance	JIRA	% of Portfolio's using Process Tool
List of Project Names for Process Compliance	JIRA	% of Projects using Process Tool
List of Process Areas per Project, Per Portfolio	JIRA	Compare to Standard SE Template Required for that IPT or Project Type
Count of CURRENT Process Areas per Project, per Portfolio	JIRA	% of Processes Following per Project out of Available defined processes in Command
Count of CURRENT PLANNED REMAIN Steps/Artifacts per Process Area, per Project, per Portfolio	JIRA	Process Compliance Trend
Count of CURRENT ACTUAL REMAIN Steps/Artifacts per Process Area, per Project, per Portfolio	JIRA	Process Compliance Trend
Date of Process Data Collection Metric Pull	SEHV Database	Process Compliance Trend

Count of PREVIOUS Process Areas per Project per Portfolio	SEHV Database	Process Area Trends
Count of PREVIOUS PLANNED REMAIN Steps/Artifacts per Process Area per Project	SEHV Database	Process Compliance Trend
Count of PREVIOUS ACTUAL REMAIN Steps/Artifacts per Process Area	SEHV Database	Process Compliance Trend

4. Data Analysis Procedure

Analysis of process compliance trend data is suggested to follow the existing procedure at SSC-A measuring process artifact conformance. This would require subtracting the count of artifacts planned to be completed per process area per project, from actual current artifacts completed and conforming. A risk could occur here depending on how the data is input into the tool(s). If users are expected to self-certify the completion of an artifact from a process, then there is no validation of artifact conformance. It is suggested to have a separate role audit and certify the artifact as complete. Table 12 displays the data analysis procedure for process compliance.

Table 12. Process Compliance Data Analysis Procedure

Indicator	**Process Compliance Trends**
Frequency of Data Reporting	As requested by authorized personnel
Responsible Individual(s)	Command Senior Leadership Staff SSC-A Executive Officer Code 01B Director of Management Operations Code 01E Director of Integration and Efficiency Code 011 Inspector General Business Portfolio Business Portfolio Manager (BPM) Deputy Portfolio Manager (DPM) Portfolio Systems Engineer (PSE)

	Integrated Product Team (IPT) Lead 5.0 Competency Tier 1 Local Competency Lead (LCL) Lead Systems Engineer (LSE) Continuous Process Improvement (CPI) Lead Process Owner Process Manager Integrated Product Team
Activity which Analyzed	Ensuring process discrepancies on projects are kept low during audits
Source of Data for Analysis	CMPro, Atlassian JIRA, SEHV Database
Tools Used in Analysis	CMPro, Atlassian JIRA, SEHV Database
Review, Report, or User	Review

5. Historical Data

SSC-A has very limited historical data related to Process Compliance. Any current compliance data would need manual input into the SEHV historical database for comparison to future collected data; otherwise, initial data collected will need to proceed through multiple iterations before enough historical data is collected to form a basis of risk to program or project health based on Process Compliance.

6. Sample Visualizations

Process Compliance Trends would display a project's required number of processes versus the actual number of processes that the project performed over time. Any deviations from expectations would trigger needed improvement efforts. Leadership and stakeholders of a project would discuss these trends during regularly scheduled reviews. Figure 29 displays an example of trends associated with technical planning.

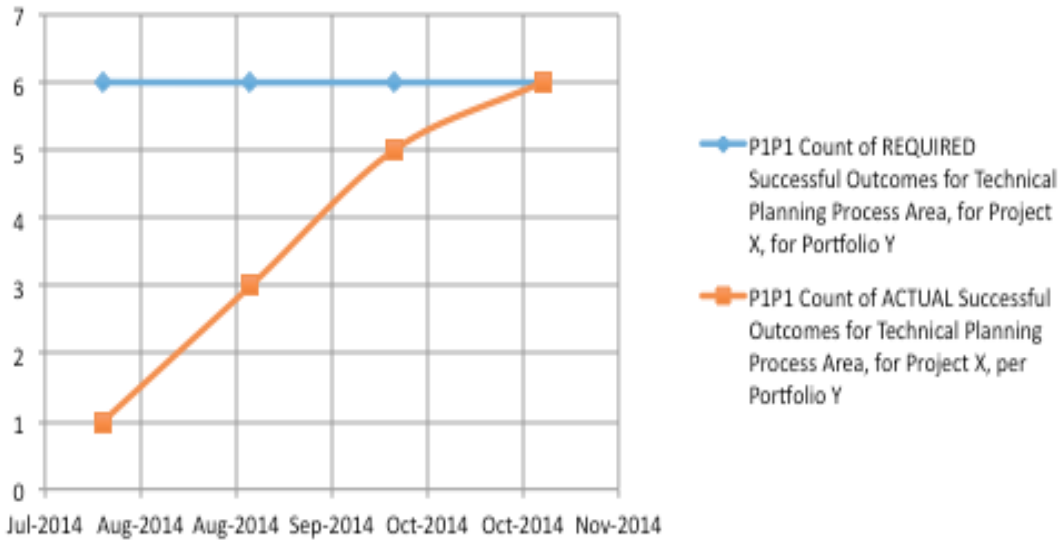


Figure 29. Example Technical Planning Process Compliance Trends

D. SELI 13, TECHNICAL MEASUREMENT TRENDS

Technical measurement is the method used to track progress of the planned Technical Performance Measures (TPMs) against the actual measured value at a particular project milestone. The TPMs are identified early in the project life cycle and planned values for the TPMs are projected based on the level of information available at the time. As the project progresses the planned profile may be updated along with the estimated value at completion. The estimated value at completion is then compared to the threshold and objective values of the TPM requirement at each milestone review which helps to facilitate decision making on how to proceed with the remainder of the project. TPMs are typically either derived from Measures of Performance (MOPs) to track system mission or functional metrics or derived from Measures of Effectiveness (MOEs) to track system cost or effectiveness metrics.

Technical Measurement involves tracking the following elements:

- Achieved-to-Date – Measured technical progress of the TPM, or estimate of progress, that is captured, recorded, and tracked at the designated milestone dates

- Planned Value – Predicted value of the TPM for the planned date of measurement based on the project plan

- Planned Profile – Series of values representing the projected time-based measurement of a TPM requirement describing the expected behavior of the TPM over time

- Tolerance Band – Limits placed on each side of the planned profile to indicate the degree of variation accepted based on risk tolerance

- Threshold – The minimum acceptable value of a TPM requirement

- Variation (or Demonstrated Technical Variance) – Difference between the "Planned Value" and the "Achieved-to-Date" value at a specific point in time

- Current Estimate – "Planned Value" at Estimate of Completion (EOC) of the TPM

- Milestones – Planned and actual dates for measurement, analysis, and review

Figure 30 is a graphical depiction of the Technical Measurement Elements.

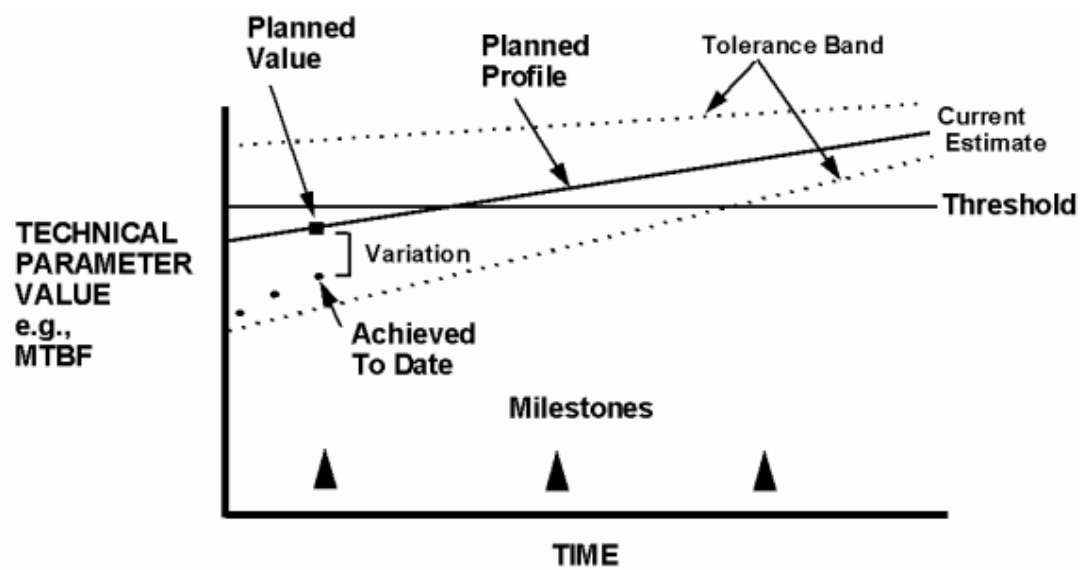


Figure 3-1 Technical Measurement Profile Illustration

Figure 30. Technical Measurement Elements (from Roedler and Jones 2005)

1. Associated Process

TPM is planned early in the life cycle and then performed with increasing levels of fidelity as the technical solution is developed. At each milestone review the TPM values and evaluated and tracked against the plan. The TPM estimate at completion can be recalculated and used to forecast whether the result falls within the acceptable range of the tolerance band. Figure 31 shows the Technical Measurement Process.

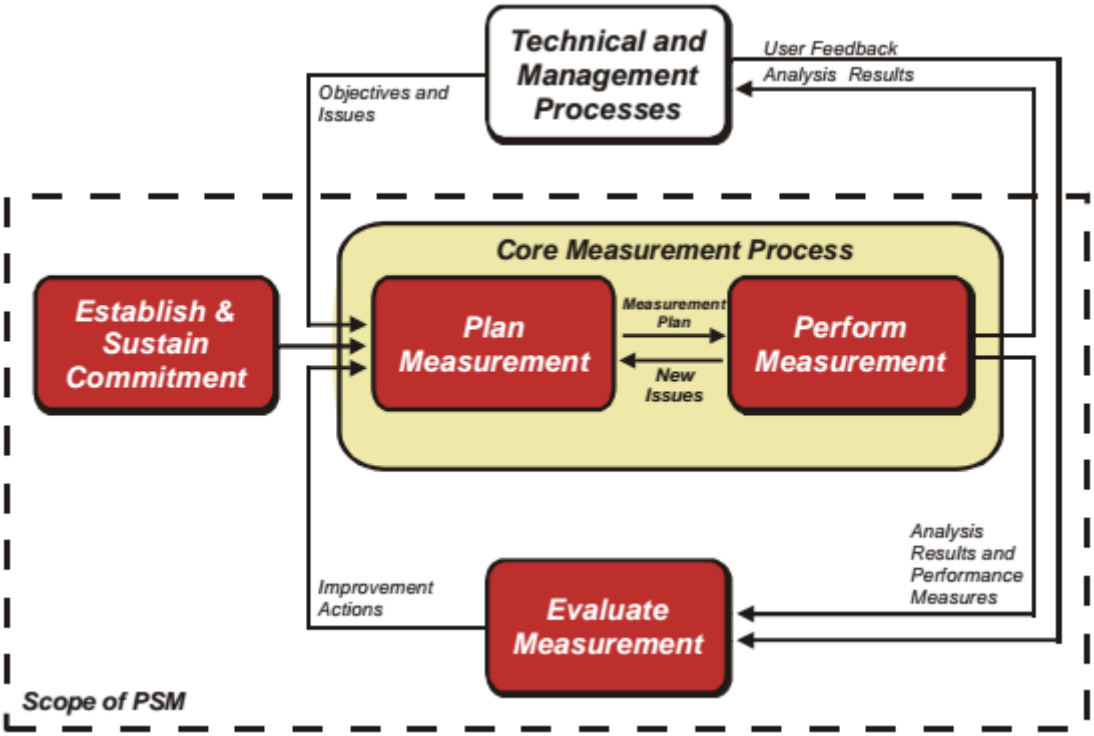


Figure 31. Technical Measurement Process (from Roedler and Jones 2005)

2. Data Collection Procedure

Extracting data from IBM Rational DOORs is required to produce SELI trends. Obtaining technical measurement data on a monthly basis will ensure up to date trends are produced. A historical database is needed to show these trends over time. Table 13 shows the data collection procedure for technical measurement.

Table 13. Technical Measurement Data Collection Procedure

Base Measure	**Data Collection Procedure**
Frequency of Data Collection	Varies based upon System Engineering Technical Review (SETR) dates One Time
Responsible Individual(s)	Lead System Engineer
Activity in which collected	Technical Risk, Requirements Analysis, Modeling, Design and Integration
Potential Sources of Data	IBM Rational DOORS (Requirements Database); Test Report; Requirements Traceability Matrix
Typical Tools used in Data Collection	Manual Input
Verification and Validation	N/A
Repository for Collected Data	SEHV Solution
Base Measure	(MOE/MOP/TPM) Estimate
Frequency of Data Collection	Varies based upon System Engineering Technical Review (SETR) dates
Responsible Individual	Lead System Engineer
Activity in which collected	Technical Risk, Requirements Analysis, Modeling, Design and Integration
Potential Sources of Data	IBM Rational DOORS (Requirements Database); Test Report; Requirements Traceability Matrix
Typical Tools used in Data Collection	Manual Input
Verification and Validation	N/A
Repository for Collected Data	SEHV Solution

Base Measure	(MOE/MOP/TPM) Actual
Frequency of Data Collection	Varies based upon System Engineering Technical Review (SETR) dates
Responsible Individual	Lead System Engineer
Activity in which collected	Technical Risk, Requirements Analysis, Modeling, Design and Integration
Potential Sources of Data	IBM Rational DOORS (Requirements Database); Test Report; Requirements Traceability Matrix
Typical Tools used in Data Collection	Manual Input
Verification and Validation	N/A
Repository for Collected Data	SEHV Solution
Base Measure	Maturity State
Frequency of Data Collection	Varies based upon System Engineering Technical Review (SETR) dates
Responsible Individual	Lead System Engineer
Activity in which collected	Technical Risk, Requirements Analysis, Modeling, Design and Integration
Potential Sources of Data	IBM Rational DOORS (Requirements Database); Test Report; Requirements Traceability Matrix
Typical Tools used in Data Collection	Manual Input
Verification and Validation	N/A
Repository for Collected Data	SEHV Solution
Base Measure	Process Phase

Frequency of Data Collection	Varies based upon System Engineering Technical Review (SETR) dates
Responsible Individual	Lead System Engineer
Activity in which collected	Technical Risk, Requirements Analysis, Modeling, Design and Integration
Potential Sources of Data	IBM Rational DOORS (Requirements Database); Test Report; Requirements Traceability Matrix
Typical Tools used in Data Collection	Manual Input
Verification and Validation	N/A
Repository for Collected Data	SEHV Solution
Base Measure	Priority Level
Frequency of Data Collection	Varies based upon System Engineering Technical Review (SETR) dates
Responsible Individual	Lead System Engineer
Activity in which collected	Technical Risk, Requirements Analysis, Modeling, Design and Integration
Potential Sources of Data	IBM Rational DOORS (Requirements Database); Test Report; Requirements Traceability Matrix
Typical Tools used in Data Collection	Manual Input
Verification and Validation	N/A
Repository for Collected Data	SEHV Solution
Base Measure	Date
Frequency of Data Collection	Varies based upon System Engineering Technical Review (SETR) dates

Responsible Individual	Lead System Engineer
Activity in which collected	Technical Risk, Requirements Analysis, Modeling, Design and Integration
Potential Sources of Data	IBM Rational DOORS (Requirements Database); Test Report; Requirements Traceability Matrix
Typical Tools used in Data Collection	Manual Input
Verification and Validation	N/A
Repository for Collected Data	SEHV Solution

3. Data Storage

Technical Measurement trend data should be stored in a historical database. This historical data can then be pulled and compared to actual current data from Technical Measurement tools used within SSC-A. Since many SSC-A projects use different tools to store their technical measurements; an interface will need to be able to collect the actual technical measurements, per project, and per portfolio at the frequency interval determined, and store within the historical database.

Table 14 shows the data elements that are suggested for collecting and storing technical measurement data.

Table 14. Technical Measurements Data Elements

Inputs/Outputs (Data Elements) Required	Tool or Data Sources	Metric/Formula used With
List of Portfolio Names for Technical Measurement Trends	IBM Rational - Quality Manager	% of Portfolio's using Technical Measurement Tool
List of Project Names for Technical Measurement Trends	IBM Rational - Quality Manager	% of Projects using Technical Measurement Tool
List of CURRENT PLANNED Quality Goals exit criteria, per project, per portfolio	IBM Rational - Quality Manager	Trend Counts of Quality Goals, per Project/Portfolio
List of CURRENT ACTUAL Quality Goals Test Values, per project, per portfolio	IBM Rational - Quality Manager	Quality Goals' Values Trends
List of PREVIOUS PLANNED Quality Goals exit criteria, per project, per portfolio	SEHV Analysis and Visualization Server	Technical Measurement Goals Trends
List of PREVIOUS ACTUAL Quality Goals Test Values, per project, per portfolio	SEHV Analysis and Visualization Server	Technical Measurement Goals Trends

4. Data Analysis Procedure

Data analysis should be performed monthly to ensure planned versus actual values are within a close range. Not meeting expected performance measures over a period of time would indicate potential risk of inaccurate performance expectations. Intervention is recommended when actual values deviate from what was originally planned over a period of time. Table 15 shows the data analysis procedure for technical performance.

Table 15. Technical Performance Data Analysis Procedure

Indicator	**Technical Performance Trends**
Frequency of Data Reporting	Varies based upon System Engineering Technical Review (SETR) dates
Responsible Individual(s)	Code 01B Director of Management Operations Business Portfolio SubPortfolio Lead (SPL) Integrate Product Team (IPT) Lead Process Owner Process Manager Tier 2 Competency Lead (CL) First-Line Supervisor Contracting Officer's Representative (COR) Integrated Product Team
Activity which Analyzed	Pre-SETR
Source of Data for Analysis	SEHV Solution
Tools Used in Analysis	SEHV Solution; Excel
Review, Report, or User	Project Manager, 5.0 Leadership

5. Historical Data

Historical Technical Measurement trend data may be obtained from IBM Rational Quality Manager and stored in the SEHV database.

6. Sample Visualizations

Technical Measurement Trends would reveal if parameters are meeting performance expectations. Any deviations from expectations would trigger needed improvement efforts. Leadership and stakeholders of a project would discuss these trends during regularly scheduled reviews. Figure 32 displays a notional example for technical performance trends.

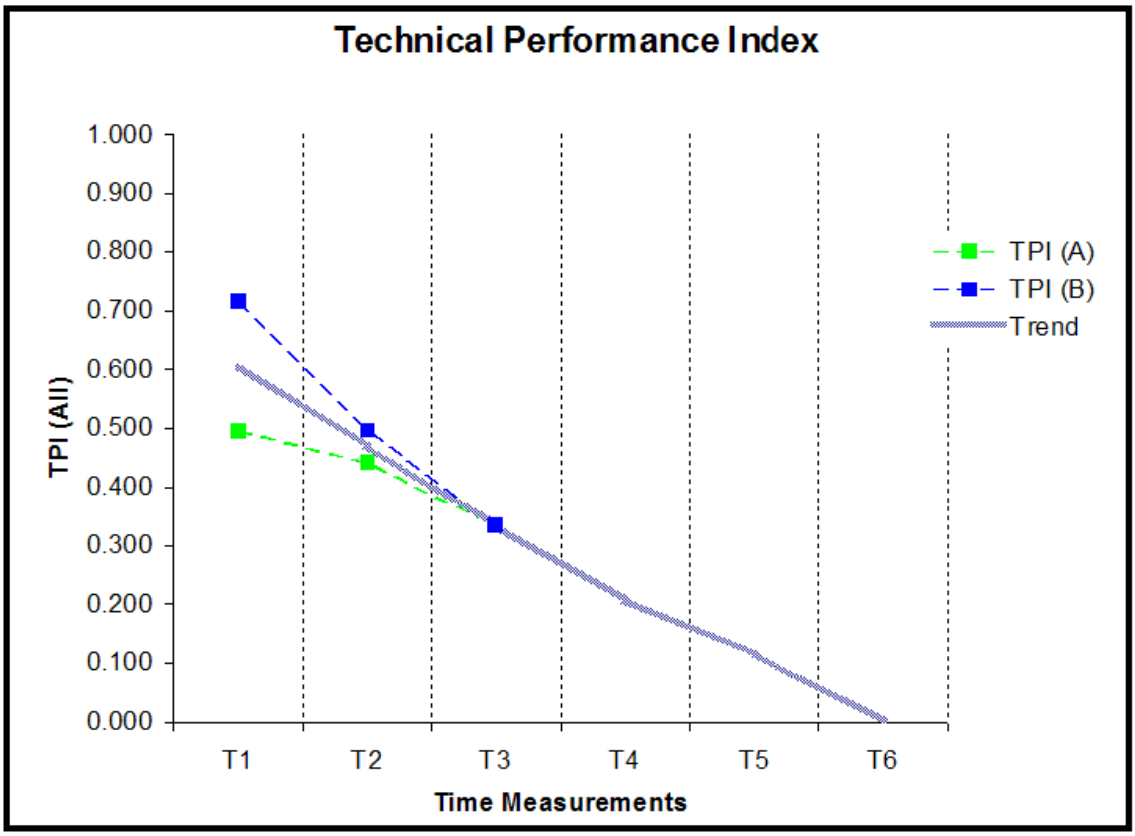


Figure 32. Technical Performance Index (from Roedler 2005)

E. SELI 16 SYSTEM AFFORDABILITY TRENDS

Planned cost expenditures along with planned obligation expenditures can be compared with actual values to display risks associated with costs over time. Funds used within the Government have an expiration date. Different appropriations of government funds such as Operations Maintenance (OM), Operations Procurement (OP), Research, Development Test and Evaluation (RDT&E) and Base Realignment and Closure (BRAC) have different lengths of time for which the funds can be used. An expiring funding document overlooked on an ACAT1 project can result in significant waste of valuable taxpayer dollars. Costs that are not actually expended on time, especially around the end of the fiscal year, can notify leadership that potential funds could be pulled to fund another critical effort. Risk exposure trends of cost with respect to schedule near the end of the fiscal year can provide visibility on a project's financial plan. Regularly scheduled

reviews within a project on this trend should display opportunities for mitigation to ensure funds are expended on time and within budget.

An actual expenditure that is greater than the initially planned expenditure will indicate that the project may run out of funds prior to the expected total expenditure date. This can cause a serious issue. Personnel being funded by that particular project risk not continuing to work to support the effort. Spending too much or too little in regards to how severe the deviation from the initial planned expenditures over time can determine the severity of the risk. Having visibility of this risk trend will expose a project's financial status and can save the government money by creating a consistent, continuous monitoring system that can show these risk trends. If a project has a recurring issue with financial management, this can be properly documented with the use of this valued SELI. Recurring financial problems can alert leadership to intervene with the project's financial situation. Using the System Affordability Trend properly will promote mitigation for obvious cost deviations from the original plan.

System affordability should be determined at several times during the course of a project. To properly manage your project each system affordability estimate should be compared and contrasted to expected values established from the original baseline budget. Figure 33 shows the relationship between project performance, measured in term of affordability and associated technical cost and schedule concerns. It also depicts that external factors (i.e., union strikes, extreme weather, budget cuts) have strong influence over project performance, and they will need to be manage properly for quality project execution.

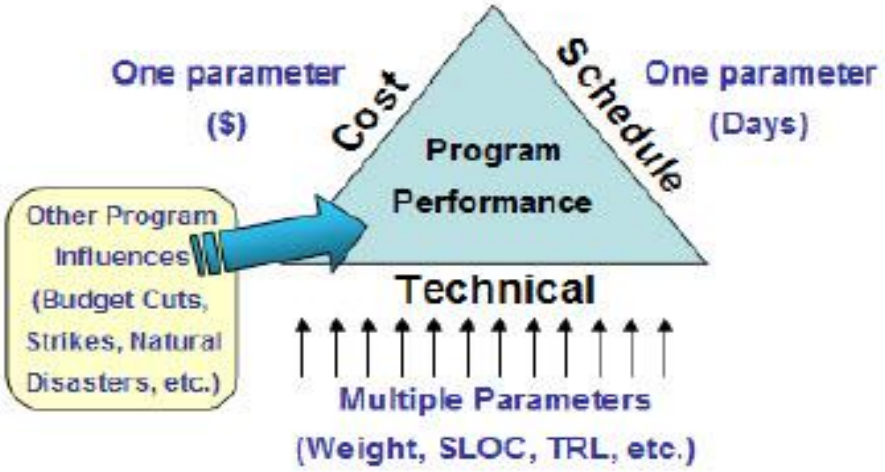


Figure 33. Project Performance measured in terms of Affordability (from INCOSE et al. 2010)

In system affordability trends, affordability is defined as the probability or confidence of achieving a stated set of needs at a stated cost and schedule. Risk is defined at the 100% confidence level to include cost, schedule and performance. When System Affordability trends are measured at different project phases (pre-concept, concept, early design, design, or implementation), it ensures the leading indicators are performing properly.

1. Associated Process

If system cost, performance and schedule criteria will be met then the system is said to be "affordable." Affordability is influence by many factors such as:

- Changes in Stakeholders Requirements
- System Definition Understanding
- Interface Demands
- Technology Maturity
- Risk Exposure
- Technical Measures

- Staffing, Resource Limitations
- Budget Cuts

All of the above factors can change during a project life cycle, and this will impact "Affordability" and its confidence levels. We need to capture the changes of the factors and relate them to affordability and confidence levels. Suppose the stakeholders wanted to change the requirements; how would this affect cost? At a new time interval that represents the changes of requirements, the project manager would determine the new cost and associated confidence levels and proposed this information to the stakeholders. If the stakeholder wants the same confidence level as before, then cost will increase, or if cost is fixed, then the confidence level will be lower. Basically these indicators imply that the requirements changes causes more project uncertainty. Therefore, the project manager should have conversations with the stakeholders to determine if changes in cost and confidence levels are something the stakeholder is willing to accept.

Figure 34 shows another approach to calculate changes in "Affordability."

$$\text{Change in Affordability} = 100\% \left(\frac{\left[\text{Baseline Effort and related confidence}\right] + \left[\sum \text{Estimated Effort}_{\text{(Impact of Changes)}} \text{ and related confidence}\right]}{\left[\text{Baseline Effort and related confidence}\right]} \right)$$

Figure 34. Affordability Calculation (from INCOSE 2010)

Changes in affordability can be obtained by adding the sum of the new changes in effort to the baseline effort and then dividing this number by the original baseline effort**.**

Measurable Concept: Is the SE effort progressing towards a system that is affordable for the stakeholders?

Leading Insight Provided: Indicates whether the merging system is affordable and what factors might be driving affordability.

2. Data Collection Procedure

Extracting data from NERP is required to produce SELI trends. Obtaining system affordability data on a monthly basis will ensure up to date trends are produced. A historical database is needed to show these trends over time. Table 16 displays the data collection procedure for system affordability.

Table 16. System Affordability Data Collection Procedure

Base Measure	● Baseline cost with associated confidence ● Planned cost with associated confidence ● Baseline effort with associated confidence ● Planned effort with associated confidence ● Baseline schedule with associated confidence ● Planned schedule with associated confidence
Frequency of Data Collection	Baseline and monthly reviews
Responsible Individual(s)	PM and IPT BFM (Business Financial Manager)
Activity in which collected	Dollars, labor hours, travel and material expenses
Potential Sources of Data	Project (Schedule), NERP (Cost)
Typical Tools used in Data Collection	Project (Schedule), NERP (Cost)
Verification and Validation	Via NERP financial report or PM excel financial spread sheets
Repository for Collected Data	NERP - Financial Excel master sheet

3. Data Storage

The SEHV system will interface and pull data from existing SSC-A system engineering and financial tool systems. The SEHV system will store project baseline, planned and actual: cost with associated confidence, effort with associated confidence and schedule with associated confidence. Cost will be in the form of dollars, effort in the form of man hours and schedule in the form of time. Table 17 displays the data elements that are suggested for collecting and storing system affordability data.

Table 17. System Affordability Data Elements

Inputs/Outputs (Data Elements) Required	**Tool or Data Sources**	**Metric/Formula used With**
List of Portfolio Names for System Affordability	NERP/P2MC	% of Portfolio's using Affordability Tool
List of Project Names for System Affordability	NERP/P2MC	% of Projects using Affordability Tool
CURRENT BASELINED COST per Project, Per Portfolio	NERP/P2MC	Baseline
CURRENT BASELINED COST CONFIDENCE per Project, Per Portfolio	NERP/P2MC	Baseline
CURRENT BASELINED EFFORT per Project, Per Portfolio	NERP	Baseline
CURRENT BASELINED EFFORT CONFIDENCE per Project, Per Portfolio	NERP	Baseline
CURRENT BASELINED SCHEDULE per Project, Per Portfolio	NERP/Project	Baseline
CURRENT BASELINED SCHEDULE CONFIDENCE per Project, Per Portfolio	NERP/Project	Baseline
CURRENT ACTUAL COST per Project, Per Portfolio	NERP	Actual

CURRENT ACTUAL COST CONFIDENCE per Project, Per Portfolio	NERP	Actual
CURRENT ACTUAL EFFORT per Project, Per Portfolio	NERP	Actual
CURRENT ACTUAL EFFORT CONFIDENCE per Project, Per Portfolio	NERP	Actual
CURRENT ACTUAL SCHEDULE per Project, Per Portfolio	NERP/Project	Actual
CURRENT ACTUAL SCHEDULE CONFIDENCE per Project, Per Portfolio	NERP/Project	Actual
PREVIOUS BASELINED COST per Project, Per Portfolio	SEHV Database	Baseline
PREVIOUS BASELINED COST CONFIDENCE per Project, Per Portfolio	SEHV Database	Baseline
PREVIOUS BASELINED EFFORT per Project, Per Portfolio	SEHV Database	Baseline
PREVIOUS BASELINED EFFORT CONFIDENCE per Project, Per Portfolio	SEHV Database	Baseline
PREVIOUS BASELINED SCHEDULE per Project, Per Portfolio	SEHV Database	Baseline
PREVIOUS BASELINED SCHEDULE CONFIDENCE per Project, Per Portfolio	SEHV Database	Baseline
PREVIOUS ACTUAL COST per Project, Per Portfolio	SEHV Database	Actual
PREVIOUS ACTUAL COST CONFIDENCE per Project, Per Portfolio	SEHV Database	Actual

PREVIOUS ACTUAL EFFORT per Project, Per Portfolio	SEHV Database	Actual
PREVIOUS ACTUAL EFFORT CONFIDENCE per Project, Per Portfolio	SEHV Database	Actual
PREVIOUS ACTUAL SCHEDULE per Project, Per Portfolio	SEHV Database	Actual
PREVIOUS ACTUAL SCHEDULE CONFIDENCE per Project, Per Portfolio	SEHV Database	Actual

4. Data Analysis Procedure

Data analysis should be performed monthly to ensure planned versus actual values are within a close range. Cost increases over a period of time would indicate potential risk of inaccurate initial estimates or unforeseen events unearthed from inadequate requirements. Intervention is recommended when actual values deviate from what was originally planned over a period of time. Table 18 displays the data analysis procedure for system affordability.

Table 18. System Affordability Data Analysis Procedure

Indicator	**System Affordability Trends**
Frequency of Data Reporting	Baseline and Monthly
Responsible Individual(s)	Code 01B Director of Management Operations Business Portfolio Business Portfolio Manager (BPM) Deputy Portfolio Manager (DPM) SubPortfolio Lead (SPL) Integrated Product Team (IPT) Lead 5.0 Competency Contracting Officer's Representative (COR) Integrated Product Team Project Manager
Activity which Analyzed	NERP reports and Microsoft Schedule
Source of Data for Analysis	NERP, labor, travel material, ODC
Tools Used in Analysis	NERP
Review, Report, or User	Monthly Report derived from NERP, Excel

5. Historical Data

Historical SE system affordability trend data may be obtained from NERP and stored in the SEHV database.

6. Sample Visualizations

Figure 35 compares a sequence of affordability distributions at various times (T1, T2, T3,) during the course of a project. Initial affordability distribution is set at the baseline cost and confidence for the stated requirements.

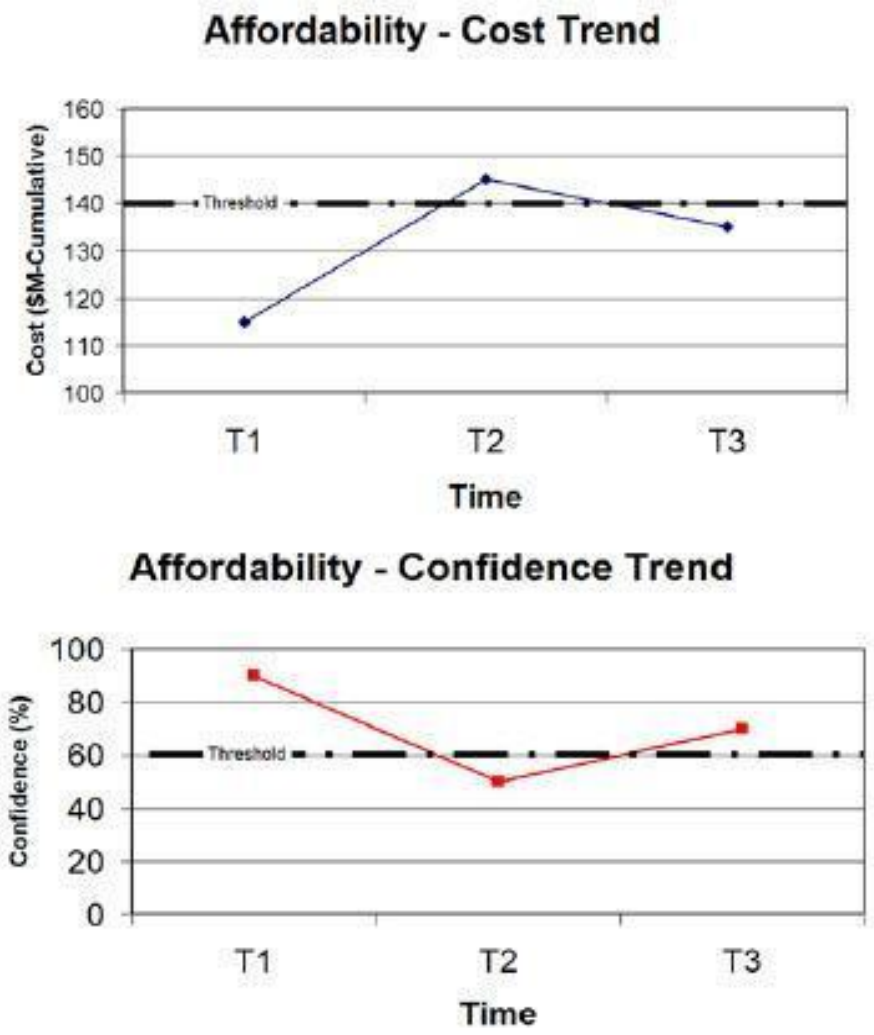


Figure 35. Affordability Cost / Confidence Trends (from INCOSE et al. 2010)

Figure 35 represents changes in affordability and confidence level as follows: The top chart represents cost trends if confidence is held constant and the second chart represents the opposite, the confidence trends if the cost is held constant. When comparing the above two charts at T1 the confidence level is high and the cost is low. At T2 cost has increased in the project and confidence level is reduced. At T3, the charts show lower cost and the confidence level has increased.

V. MODELING AND SIMULATION

Modeling and simulations help portray processes in a virtual environment. Predicting potential outcomes from simulations assist with facilitating a way forward for decision makers. Gaining insight from simulation outcomes can display current process as well as potential areas for improvement. The continuous effort for reducing inefficient processes can result in cost saving opportunities, performance enhancements, and time reducing options. Optimizing operations by simulating a current process and proposing a more efficient solution will communicate the feasibility of a possible future plan. Models and simulations show real world activities under different conditions while saving on costs by reducing the need to perform activities manually. Refining models to illustrate real world scenarios add value to continuous process improvement initiatives. The ExtendSim simulation contains timing values for 8-hour days, 5 days a week. This would align with the standard DOD 40-hour workweek. Process delays were simulated using triangular distributions containing minimum, maximum, and most likely values.

The need for the most up-to-date information is always preferred. The more current the data, the earlier leadership could take action on potential risk areas. Consistent fresh data would benefit SSC-A by depicting the current health of the organization with respect to SE. The current manual data call process usually results with data that is slightly outdated. The staleness of the data received by leadership was analyzed during the Manual and SEHV simulations.

A. MANUAL MODEL

The manual data call process involves multiple personnel to complete the process. The start of the manual data call typically comes down from leadership where a specific measure is requested. Measures are helpful for a particular instance of time, however, they are even more beneficial when being captured consistently, accurately, and compared against historical data. The tedious data call process would begin by distributing emails requesting various measures. Excel sheets would typically be populated with the data requested by leadership and filled out by IPT members. The IPT

members would send the measures back to the IPT lead or requestor for review. If the data is accepted by the IPT lead or requestor, the data is then sent to the Strategic Analysis and Decision Support (SAnDS) team to review and upload to these measures for visual trending depictions. If the measures that the IPT member submitted were questionable or incorrect, the reviewer would send an email requesting clarification or correction. The manual data call simulation displays this concept by simulating a path back to the originator of the email.

The simulation shows personnel taking action on their part of the data call, whether it is inputting the data, reviewing the data, or requesting measures. Delay values were set for each action taken by personnel to point out areas where potential risk could take place in regards to having a successful data call. These simulations do not account for personnel who are on leave, sick, or unable to perform the task during the process. A hundred data calls were simulated to obtain an average amount of time a data call would take to complete. Figure 36 shows the ExtendSim manual data call process model.

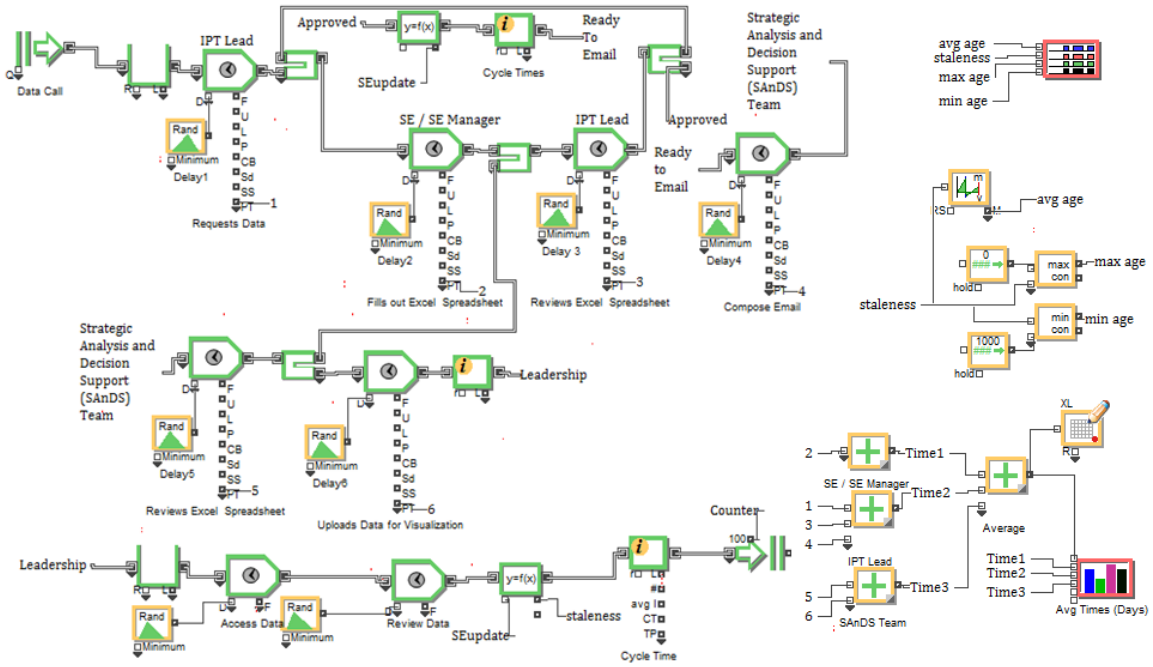


Figure 36. ExtendSim Manual Data Call Process Model

B. GENERIC SEHV MODEL

Figure 37 depicts the SEHV model which automates a part of the SE data call process by utilizing a methodology entailing data to be captured, stored, analyzed, and displayed. The SEHV methodology allows users to perform SE functions using SE tools while data captured from these tools would display trends to leadership that indicate potential project risk. This alternative to the manual SE data call would gather data without being disruptive to personnel. Information requested by leadership (i.e., SE data calls) would be available at their convenience by having access to the SEHV display capability. As shown in the figure, leadership would have their own process where they would access the SEHV database and be able to select the visualization trends of current and historical SE data. SE / SE management would perform SE functions on a regular basis using SE tools without being asked by leadership to provide SE data. The SEHV system would split the typical data call process into two by allowing an automated methodology to provide services to leadership and the SE / SE manager by performing functions such as capture, store, analyze, and display.

This simulation assumes tools being used by SE / SE management have the capabilities to input the required data elements for visualization. Another assumption would include that leadership, and SE / SE managers are trained on the SEHV system and understand how to use SE tools associated with data capture by the SEHV system.

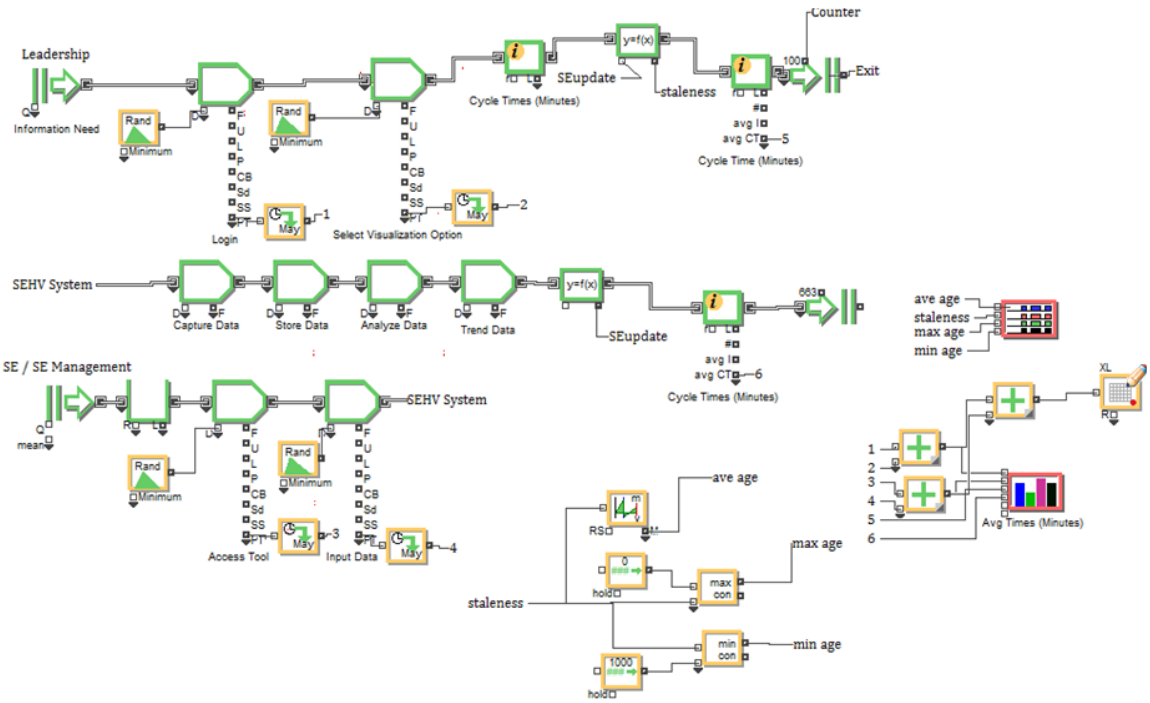


Figure 37. ExtendSim SEHV Process Model

C. MANUAL VERSUS SEHV COMPARISONS

Typical information requested by leadership (i.e., data calls) would disrupt the SE / SE managers, IPT leads, or any IPT member from their usual daily tasks. Coordination between leadership and data collectors would have to be established in order to organize a strategy to collect data needed. Consistency of the data being provided and data requested is essential for having a successful data call. The SEHV system would allow SE / SE managers not to be disturbed by data calls, but promote a means of performing SE / SE activities within SE tools while data needed would be collected in a non-disturbing fashion.

1. Manual Simulation

Simulating the manual data call process involved displaying the "staleness" values over multiple iterations of data calls. The average age, staleness, max age, and min age was recorded to display how stale data could be from a manual data call process. Considering the 5 day work week, the results indicate that data could be as old as a couple of months. Stale data could re-engage leadership in requesting more updated data

right after a data call has been completed. The average data call would be completed within a month. Figure 38 displays the staleness of data from the manual process.

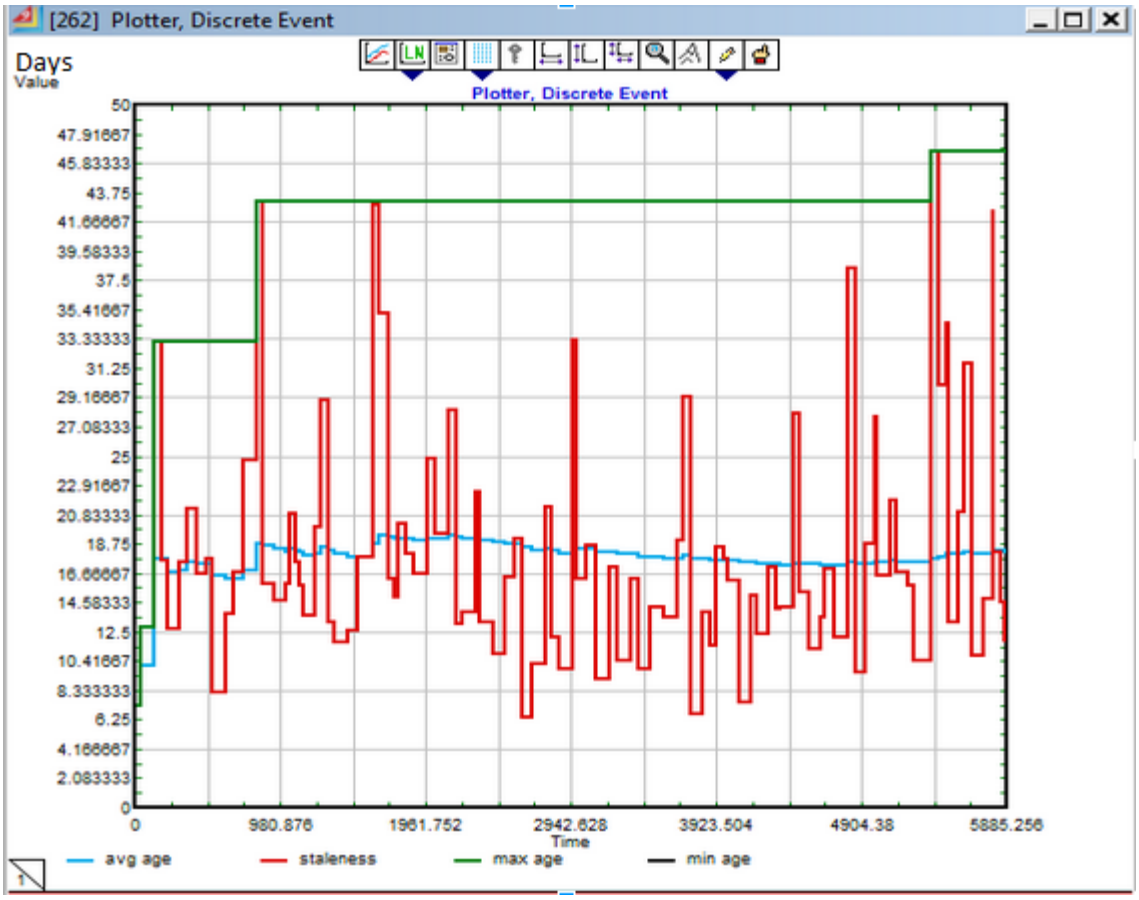


Figure 38. ExtendSim Manual Data Call Staleness

The processing time was collected to see how much of a delay there was within the manual data call process. The IPT lead would have to coordinate a strategy to collect the data from each SE / SE manager once notified by leadership. The SE / SE manager would react to the data call by acknowledging its existence, and plan to fulfill the data call requirement when time permits. Depending on whether the data call request is answered correctly, rework for the submitted information would be possible. The IPT lead would have to review the data received to ensure the data call is answered sufficiently. Passing this data off to the SAnDS team, would require the SAnDS team to review and upload the data for visualization purposes. The process for the IPT lead

orchestrating the strategy for collecting data from the SE / SE manager(s) and reviewing the data for accuracy would take over a week. The SE / SE manager fulfilling the data call request would typically be given a week to provide the data requested. This tedious process would have an average of a month to complete a successful data call. Figure 39 displays the results of the manual simulation that performed 100 iterations of the process.

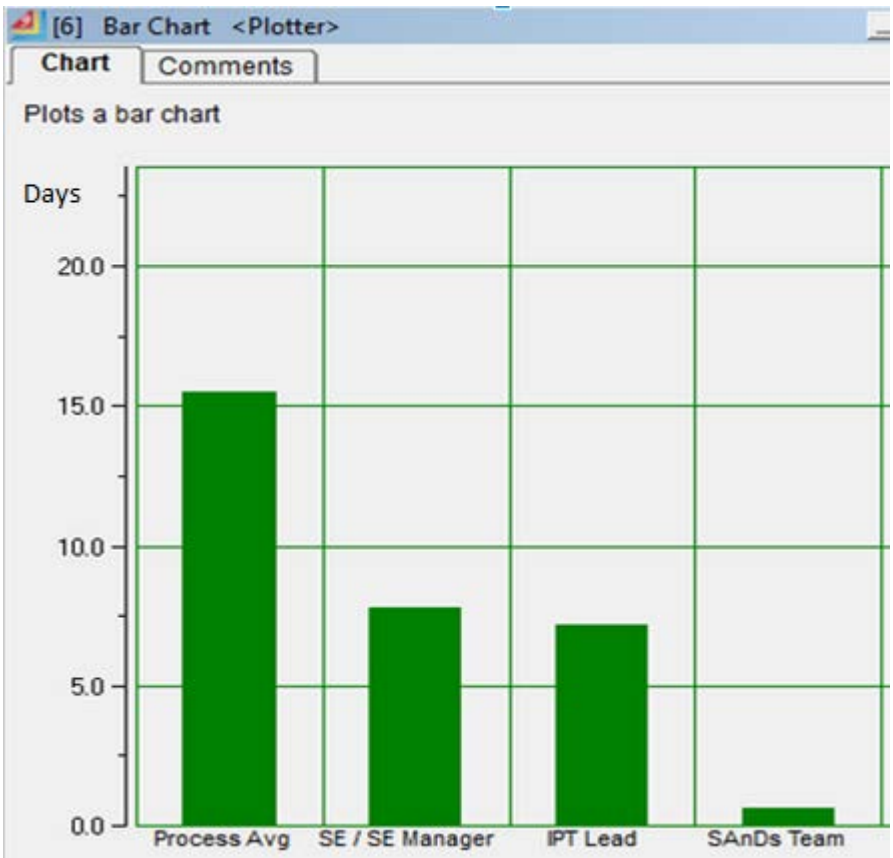


Figure 39. Manual Process Times

Figure 40 displays the distributions for the values, where the standard deviation was a few days. The 25% quartile illustrated approximately 11 working days while the 75% quartile depicted approximately 15 working days. The values distributed clearly show that stale data is present at the completion of a data call.

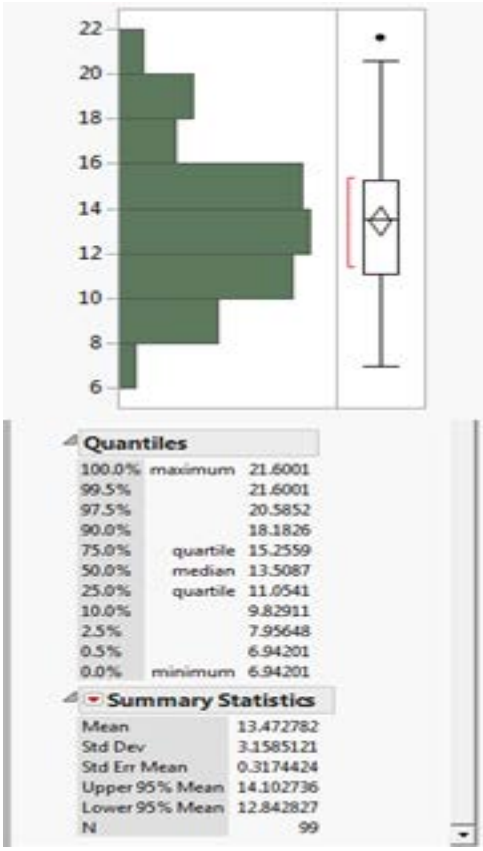


Figure 40. Manual Process Distribution in Days

2. SEHV Simulation Results

One of the key points for the comparison is the number of people involved in the process. The greater the number of people involved in any process creates a more likely occurrence of a process delay or even work stoppage. The more people there are within SSC-A's typical data call process, the more risk of an unsuccessful data call occurring. People replaced with automated technology can decrease the chances of human error. Technology can reduce the dependency of personnel performing specific tasks. Maintenance of electronic components is always a necessity; however the right redundancy or backup component can help alleviate potential problems. Redundancy with human personnel is possible, but having an exact clone that performs exact functions is highly unlikely. Limiting the amount of personnel within a data call process will decrease the amount of human error, increases the chances of repeatability, increases the speed of the process, and promotes a more efficient process.

The SEHV solution includes SE / SE manager(s) to perform their SE duties using SE software tools. Assuming the SE / SE manager is trained to use the SE software tools, the staleness of data would be on average a week old. Consistent data collection by automated processes assists with having current "fresh" data. Regular use of SE tools would be a requirement to obtain data for visualization. Figure 41 displays the ExtendSim SEHV results.

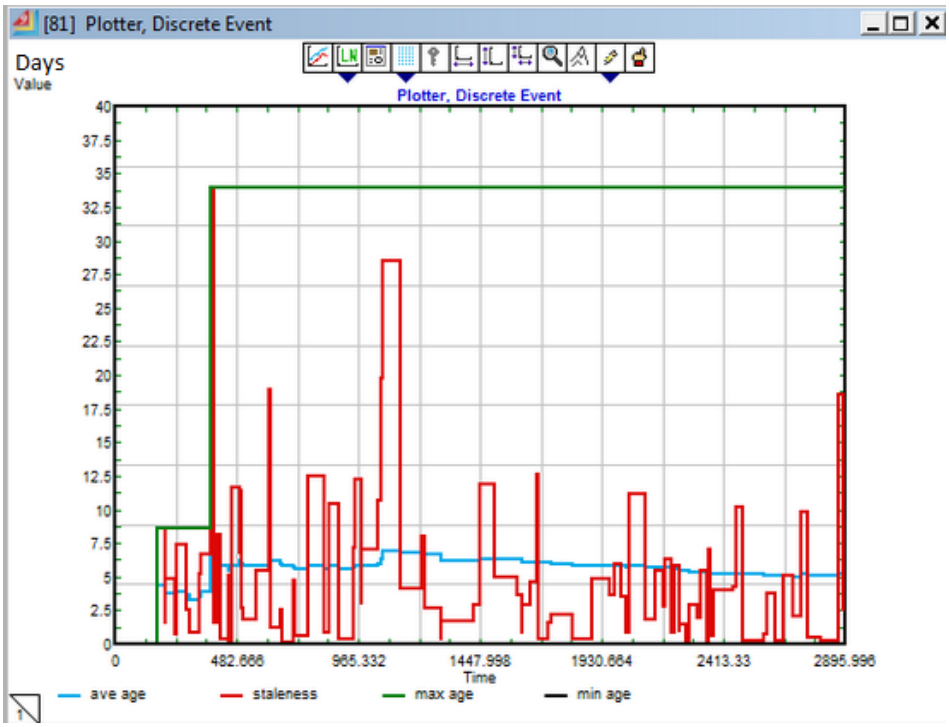


Figure 41. ExtendSim SEHV Process Staleness

Process times for SE functions performed were captured to observe averages and instances of time spent on SE and leadership activities. The average time for the SEHV process resulted in about 45 minutes. SE / SE management would use SE tools while the SEHV system would collect and provide the data to leadership for viewing purposes. Figure 42 displays process times for leadership (Process Time: L), and SE / SE management (Process Time: SE).

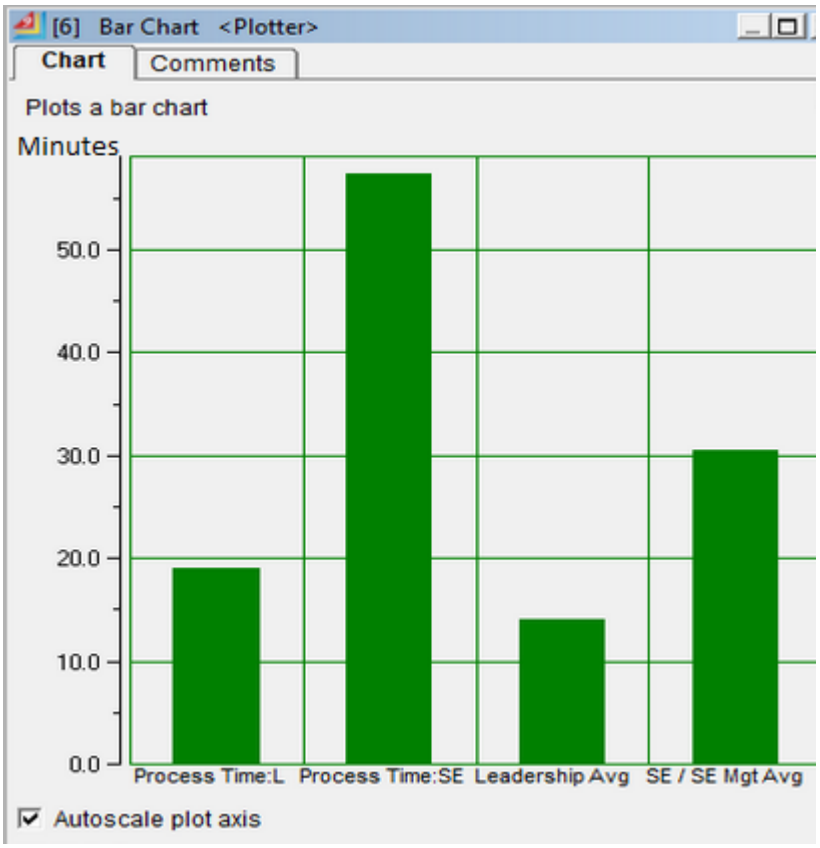
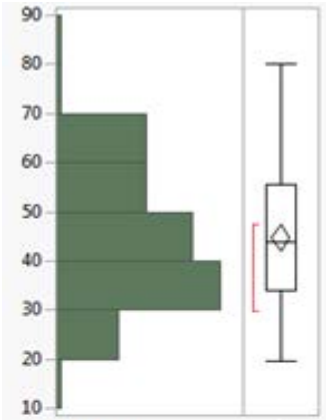


Figure 42. SEHV Process Times

The SEHV process times were captured to point out the need for a consistent and continuous methodology for data calls. The luxury of performing SE functions while allowing leadership to obtain data via the SEHV system will help eliminate inefficient processes. The 25% quartile was around 34 minutes while the 75% quartile was close to an hour. These values represent the combined effort of both leadership obtaining the desired visualization option and SE / SE Management performing necessary SE activities with SE software tools. These values were set to minutes since leadership obtaining data would be at their own leisure. SE / SE management would regularly update SE tools as part of their normal duties. Figure 43 displays SEHV process distributions.



Quantiles

100.0%	maximum	80.1145
99.5%		80.1145
97.5%		73.1343
90.0%		62.9539
75.0%	quartile	55.4447
50.0%	median	43.8989
25.0%	quartile	34.0152
10.0%		28.8406
2.5%		22.5744
0.5%		19.7084
0.0%	minimum	19.7084

Summary Statistics

Mean	44.820278
Std Dev	13.384222
Std Err Mean	1.345165
Upper 95% Mean	47.489714
Lower 95% Mean	42.150842
N	99

Figure 43. SEHV Process Distribution in Minutes

3. Experiments

Frequency, of how often the SEHV methodology should be implemented, was determined by providing various frequency inputs to obtain results. Different results were analyzed to compare the age or "staleness" of the data delivered. Triangular distributions were used to have random amounts of days within a range of possible frequency inputs. The less frequent SE / SE Management uses SE software tools assisting the SEHV effort, the more outdated the data would be once leadership obtains the visual trends. This was proven in the SEHV ExtendSim simulation. The right amount of time to be able to react to potential project risk at all levels whether its leadership, portfolio, IPT, or competency is critical to the decision maker.

Using 5-day 40-hour workweeks to replicate current SSC-A work requirements would assist the simulation to determine the frequency of SE software tool use. A triangular random value distribution was used to simulate data input of SE / SE management personnel. Performing SE / SE management functions within SE tools using values of range of frequencies from the following:

Simulation Frequency Experiment 1
Minimum: 5 days
Maximum: 15 days
Most Likely: 10 days

Simulation Frequency Experiment 2
Minimum: 10 days
Maximum: 20 days
Most Likely: 15 days

Simulation Frequency Experiment 3
Minimum: 15 days
Maximum: 25 days
Most Likely: 20 days

Simulation Frequency Experiment 4
Minimum: 20 days
Maximum: 30 days
Most Likely: 25 days

Weekly (five day) increments were inserted into the simulation to obtain a MS Excel spreadsheet of data from 100 iterations during each experiment. Analytical software JMP was used to compare the distributions among the simulation runs. Reviewing the results and Experiment 3 with data staleness of a mean of 10 days is sufficient to observe current, up to date risk trends. Although some projects may use SE / SE management tools more frequently, a requirement of inputting data into these tools at least once a month by personnel is recommended to have the most up to date visualization trends. Figure 44 and Figure 45 display the results of the simulation frequency experiments.

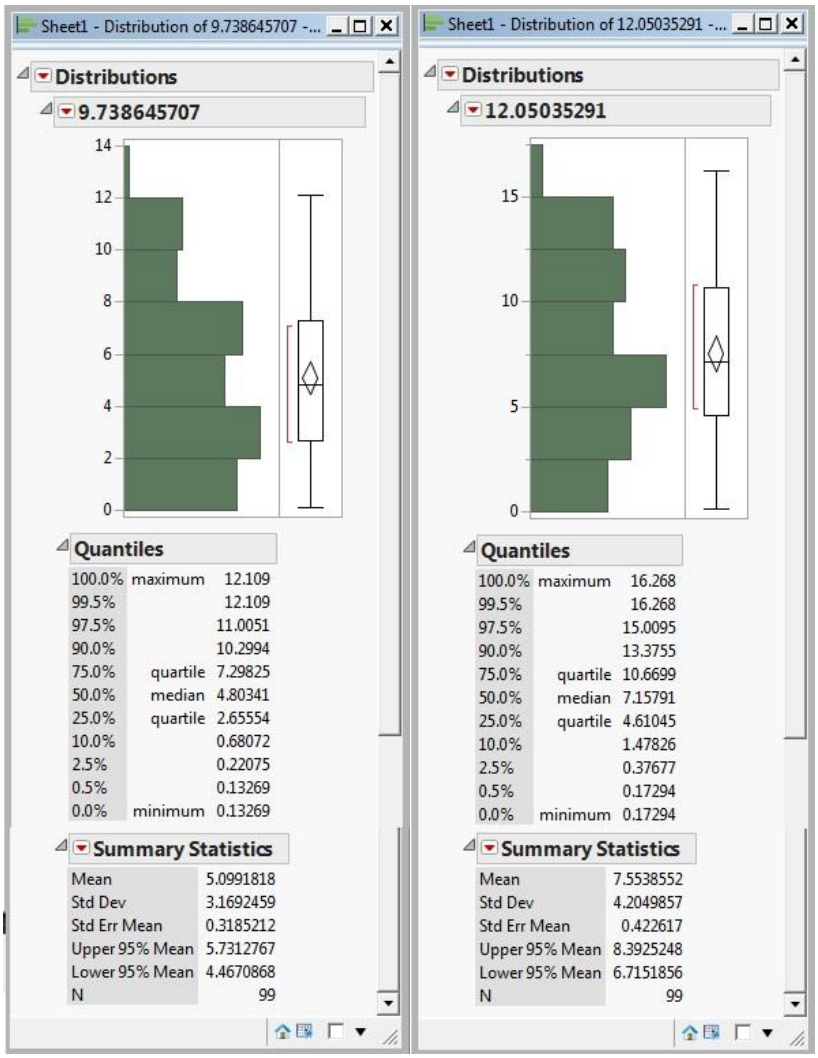


Figure 44. Simulation Frequency Experiment 1 and 2

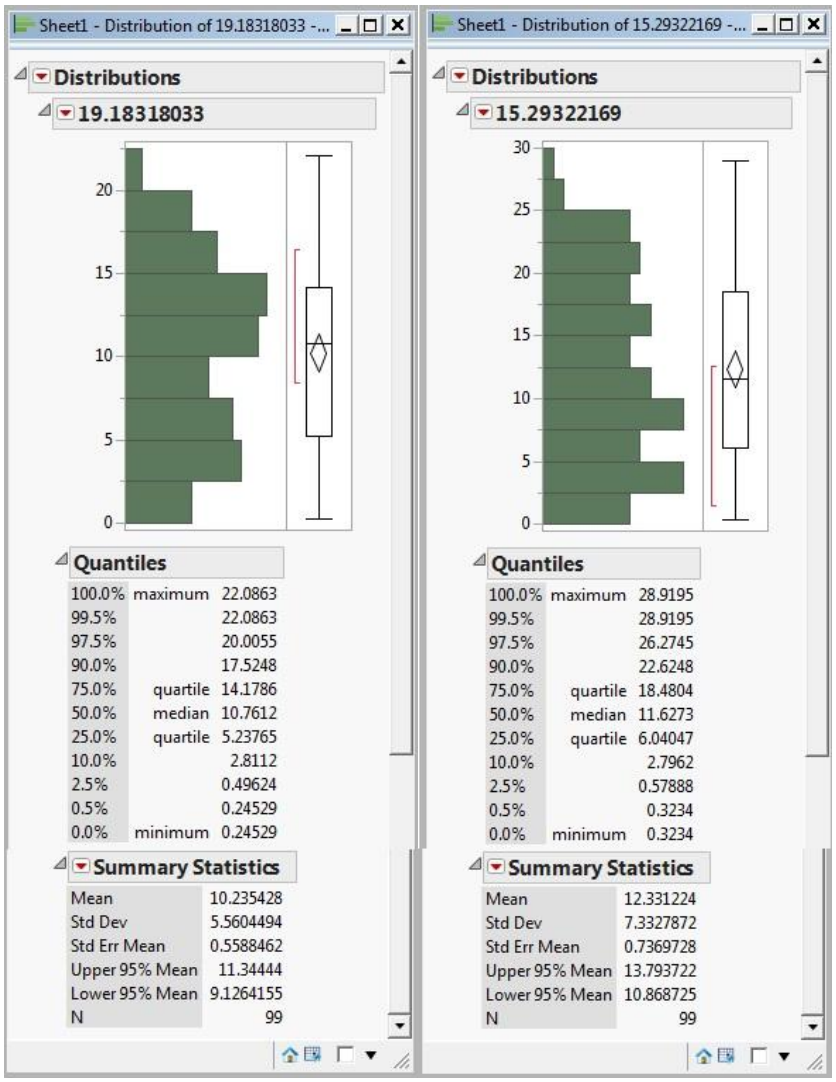


Figure 45. Simulation Frequency Experiment 3 and 4

4. Conclusion

Creating a model, for both the SEHV and manual data call processes, assisted with simulation in a virtual environment. Inefficiencies were observed within the manual data call process where potential delays would increase the risk of having a timely data call. Reducing risk by reducing delays would promote overall efficiency. Automating areas within the data call process would save time and money by taking away manual human efforts that have possible room for error. Performing SE / SE Management functions within SE software tools at least once a month would satisfy the need of having consistent, up-to-date visualization trends.

THIS PAGE INTENTIONALLY LEFT BLANK

VI. SYSTEM ANALYSIS

The SEHV system, although having many reusable concepts for other engineering organizations or enterprises, in this case only applies to the SSC-A application. In that sense, this analysis will focus on mostly the Cost, Schedule and Performance within the SSC-A boundary.

A. COST ANALYSIS

The estimated costs of the SEHV System options were developed and evaluated at a high level based on several reasons and assumptions. The team identified each of the major cost categories that would require material and/or labor effort to perform and estimated rough values for each based on the options capabilities or specific requirements. The first option was to continue performing the Systems Engineering data calls via manual method. Even though the manual solution has proven to be unable to provide SSC-A with a consistent format for visualizing combined results based on stakeholder roles, it was still included in the cost analysis for comparison in order to show any cost benefits that result in addition to performance increases. The second option, the Automated Hybrid option, was selected based on the AHP data determining this automated solution to perform better suited to SSC-A stakeholder needs. Each of the other Automated procurement solutions would both have similar cost savings; however, the assumed development and integration costs for the complete GOTS solution would far exceed the COTS or Hybrid options. This assumption could also be re-evaluated based on COTS maintenance and licensing fees. We assume that the COTS solution would cost less to develop than the Hybrid Solution would; however, estimating those costs would only serve to show a greater or similar potential savings than what the Hybrid would provide.

Each of the cost areas for the SEHV solutions was identified based on the system functional architecture. The estimated cost of each option was broken out by the systems engineering and logistics life-cycle described by the SSC-A Framework.

1. Manual Method Costs

It is estimated that each project or systems engineer provides data required filling at least one data call per project, and that ten projects are managed each year on average by each. With approximately 1000 project engineers at SSC-A managing this average project load, it is expected that 10000 annual data calls will be requested. Some data calls come from Competency Leads, some come from the Portfolio, and some come from customers. On average it is expected to take four hours of labor to collect, analyze, and provide an approved display of the requested project data. This does not include any waiting time. Weekly Action Reports alone are an example of one recurring data call that absorbs approximately 30 minutes of consolidated reporting each week from the SE or IPT Lead, per project. Some of these identified projects are actually groups of multiple similarly tasked projects, each requiring weekly update information. If a data call is defined as a higher level request from the customer or command leadership, then it will offset the average expected data call labor effort time spent to respond.

When evaluating the estimated cost for performing manual data calls, both fixed and variable costs were identified. For fixed costs, it is assumed that data was collected, stored, and analyzed on the project engineers' computer and monitor. For variable costs, we assumed that each time a data call is requested, it takes the project engineer two hours to collect the data in the necessary format, and it takes the IPT lead one hour to analyze and one hour to develop the display required. This is a total of four estimated hours of labor per data call.

A mathematical function demonstrating this manual cost per data call can be shown as Y=$3000 + $400X, where Y is the total cost and X is the number of manual data calls, assuming $100 per hour of labor. The $3000 is a fixed representation of any material costs necessary to provide those manual data calls.

The team assumes no further costs added or saved will apply to this function over time due to constant changing projects and engineers.

For 10000 annual data calls, it is estimated that the total cost is close to $4 million each year for SSC-A to staff and provide.

2. Automated Hybrid Solution Costs

For the Automated Hybrid Solution, costs were also separated by fixed and variable as shown in Figure 47. In addition, SE planning, design, testing, pre-deployment, implementation, modification, operation, and maintenance costs were also considered. For the first year, the estimated costs minus operation and maintenance were just under $1 million. Annual operation and maintenance costs included approximately $400,000.00 for maintenance, and only about 1.2 hours of operating labor effort are required per data call. This reduced labor time per data call can be extracted from the simulation which is based on standard consistent and automated process for collecting, analyzing, and displaying SE health visualizations. This cost can be represented with a function Y=$400,000 + $120X, where Y is the total cost and X is the number of automated data calls, assuming $100 per hour of labor.

The team assumes that cost changes after the first year will be 10% more or less due to software license additions or deletions, as well as the removal of the costs to plan, design, test, pre-deploy, implement, and modify the Hybrid tools for use.

Estimating the operation and maintenance cost for 10000 expected data calls at SSC-A using the Hybrid Solution method cost $1.6 million.

Compared to the manual method, this is a savings of $1.4 million for the first year and $2.4 million for each year thereafter.

When comparing this method's costs to the manual method, the operations and maintenance break even cost and number of data calls, when each of the cost equations are solved together for X and Y. This results in X=1418 data calls, at a cost of approximately Y=$567,000.00. However, since that cost is less than the Hybrid Solution annual operation and maintenance cost, we would need to find the minimum number of manual data calls required per year that would equal the cost of operating and maintaining the Hybrid Solution. By setting the $1.6 million Hybrid O&M cost equal to $3000 + $400,000X, it can be found that if 3993 data calls or more are requested per year by SSC-A, then it would be an annual cost savings to invest in the Automated Hybrid Solution. Figure 46 and 47 displays the spreadsheet cost detail data for each of these two

options. The other options were not addressed as the AHP lead to the Automated Hybrid Solution.

MANUAL METHOD (Current Majority)		Avg. Expected Time Per Function (Hrs)	FIXED COSTS			VARYING COSTS					Total Cost
SEHV OPTION 1 Cost Breakdown Structure			Labor ($/hr)	Material	Total Fixed	Labor ($/hr)	Material	Frequency	Est. # of Events per Freq.	Total Variable Cost	
Planning Activities	Concept Need	0	$100.00		$0.00	$100.00				$0.00	
SE Tasks	Requirements	0	$100.00		$0.00	$100.00				$0.00	
	System Architecture	0	$100.00		$0.00	$100.00				$0.00	
OPTION 1	MANUAL METHOD (Current Majority)		$100.00		$0.00	$100.00				$0.00	
Design	Data Collection Methods	0	$100.00		$0.00	$100.00				$0.00	
	Data Analysis	0	$100.00		$0.00	$100.00				$0.00	
	Data Display	0	$100.00		$0.00	$100.00				$0.00	
Testing	Data Collection Methods	0	$100.00		$0.00	$100.00				$0.00	
	Data Analysis	0	$100.00		$0.00	$100.00				$0.00	
	Data Display	0	$100.00		$0.00	$100.00				$0.00	
Pre-Deploy Req's	Training Docs	0	$100.00		$0.00	$100.00				$0.00	
	Training Implement	0	$100.00		$0.00	$100.00				$0.00	
Implementation	Data Collection Methods	0	$100.00		$0.00	$100.00				$0.00	
	Data Analysis	0	$100.00		$0.00	$100.00				$0.00	
	Data Display	0	$100.00		$0.00	$100.00				$0.00	
Modification	Data Collection Methods	0	$100.00		$0.00	$100.00				$0.00	
	Data Analysis	0	$100.00		$0.00	$100.00				$0.00	
	Data Display	0	$100.00		$0.00	$100.00				$0.00	
Maintenance	Data Collection Methods	0	$100.00		$0.00	$100.00				$0.00	
	Data Analysis	0	$100.00		$0.00	$100.00				$0.00	
	Data Display	0	$100.00		$0.00	$100.00				$0.00	
Operation	Data Collection Methods	2	$100.00	$2,500.00	$2,700.00	$100.00		Data Call/ Yr	10000	$2,000,000.00	$2,002,700.00
	Data Analysis	1	$100.00	$2,500.00	$2,600.00	$100.00		Data Call/ Yr	10000	$1,000,000.00	$1,002,600.00
	Data Display	1	$100.00	$500.00	$600.00	$100.00		Data Call/ Yr	10000	$1,000,000.00	$1,000,600.00
Operation Labor Hrs											$4,005,900.00
	IPT Lead	1									
	SE/ SE Mgr	2									
	SanDs Team	1									

Figure 46. Manual Method Costs Details

Automated Hybrid COTS Tools with Central Database		Avg. Expected Time Per Function (Hrs)	FIXED COSTS			VARYING COSTS					Total Cost
SEHV Hybrid OPTION Cost Breakdown Structure			Labor ($/hr)	Material	Total Fixed	Labor ($/hr)	Material	Frequency	Est. # of Events per Freq.	Total Variable Cost	
Planning Activities	Concept Need	40	$100.00		$4,000.00	$100.00				$0.00	$4,000.00
SE Tasks	Requirements	120	$100.00		$12,000.00	$100.00				$0.00	$12,000.00
	System Architecture	120	$100.00		$12,000.00	$100.00				$0.00	$12,000.00
OPTION 2	Automated Hybrid COTS Tools with Central Database		$100.00		$0.00	$100.00				$0.00	$0.00
Design	Data Collection Methods (From Tools)	40	$100.00	$15,000.00	$19,000.00	$100.00		Tools/Design	10	$40,000.00	$59,000.00
	Data Analysis	20	$100.00		$2,000.00	$100.00		Tools/Design	10	$20,000.00	$22,000.00
	Data Display	20	$100.00		$2,000.00	$100.00		Tools/Design	10	$20,000.00	$22,000.00
Testing	Data Collection Methods	60	$100.00		$6,000.00	$100.00	$2,500.00	Tools/Test	10	$85,000.00	$91,000.00
	Data Analysis	20	$100.00		$2,000.00	$100.00		Tools/Test	10	$20,000.00	$22,000.00
	Data Display	20	$100.00		$2,000.00	$100.00		Tools/Test	10	$20,000.00	$22,000.00
Pre-Deploy Req's	Training Docs	40	$100.00		$4,000.00	$100.00		Train Doc/Tool	10	$40,000.00	$44,000.00
	Training Implement	8	$100.00		$800.00	$100.00		Train /Tool	10	$8,000.00	$8,800.00
~50 Licenses	Procurement of Tools	20	$100.00		$2,000.00	$100.00	$25,000.0	Purchase/Tool	10	$270,000.00	$272,000.00
Implementation (For ~50 Projects) (4hrs/Project)	Data Collection Methods	200	$100.00		$20,000.00	$100.00		Import/Tool	10	$200,000.00	$220,000.00
	Data Collection Tool Activatio	50	$100.00		$5,000.00	$100.00		Per Tool	10	$50,000.00	$55,000.00
	Data Implement Testing	100	$100.00		$10,000.00	$100.00		Per Tool	10	$100,000.00	$110,000.00
Modification	Data Collection Methods	80	$100.00		$8,000.00	$100.00				$0.00	$8,000.00
	Data Analysis	40	$100.00		$4,000.00	$100.00				$0.00	$4,000.00
	Data Display	40	$100.00		$4,000.00	$100.00				$0.00	$4,000.00
Maintenance (1 Yr)	Data Collection Methods	2000	$100.00	$5,000.00	$205,000.00	$100.00				$0.00	$205,000.00
	Data Analysis	2000	$100.00	$5,000.00	$205,000.00	$100.00				$0.00	$205,000.00
Cmd Dashboard?	Data Display	200	$100.00	$1,000.00	$21,000.00	$100.00				$0.00	$21,000.00
Operation	Data Collection Methods	1	$100.00	$2,500.00	$2,600.00	$100.00		Data Call/ Yr	10000	$1,000,000.0	$1,002,600.00
	Data Analysis	0.1	$100.00	$2,500.00	$2,510.00	$100.00		Per Data Call	10000	$100,000.00	$102,510.00
	Data Display	0.1	$100.00	$500.00	$510.00	$100.00		Per Data Call	10000	$100,000.00	$100,510.00
											$2,628,420.00

Figure 47. Automated Hybrid COTS Tools with Central Database Costs Details

B. PERFORMANCE

SEHV performance measures include consistency, timeliness of data, and accuracy of data captured for trending visualization. The performance of the current data call process is inefficient and needs the SEHV methodology to assist. Accuracy of data would include using the SE software tools to input information with respect to the project. This would alleviate potential errors created by the manual method of entering in data onto an excel sheet for the intent of uploading the data into visualization software.

An assumption that SE tools provide the required data elements that SELI trends require to produce visualization graphs was acknowledged during the course of this Capstone. Another assumption was that the command will enforce the use of the SEHV system for projects to input their data into the agreed upon SE software tools. The use of these tools would include a frequency of entering in data of at least once a month to obtain fresh data. The SEHV methodology is assumed to be accepted and utilized within SSC-A.

There is a maintenance risk for the SEHV system. Troubleshooting integration issues that may arise due to IA patches or software updates, would require subject matter experts of the system to be able to mitigate potential problems. A team would have to be trained, and possibly be involved with the development of the SEHV system itself in order to adequately be able to provide helpdesk support when issues arise. Another risk would include projects that deal with sensitive information that cannot expose certain SELIs such as technical performance measures, risk exposure, or any other SELI that may affect the classified nature of a particular system. Operational availability of the SEHV system would also be a risk if redundant components are not put in place to have an adequate failover method. Having a backup database and SEHV server would reduce the probability of having a catastrophic failure.

C. POTENTIAL SYSTEM RISKS

Table 19 displays potential risks for the SEHV system. These potential risks may prevent the SEHV system from being successful at SSC-A, and should be considered along with details depicted within this report. Each risk listed has a mitigation strategy to reduce risks for developing the SEHV system.

1. Inconsistent use of SE / SE Management tools can create discrepancies when data collection occurs.

   Mitigation – Set a minimal operational requirement for SEHV users to input data, provide training, and document standard operating procedures.

   Risk Justification – Medium impact with a low probability since planning objectives can be put forth prior to SEHV system deployment.

2. SEHV system development cost may vary due to lack of detailed system specifications required.

   Mitigation – Complete a market survey, economic study, and develop a prototype prior to implementing the SEHV system deployment effort.

   Risk Justification – Medium impact and low probability since additional cost analysis efforts can be performed.

3. Information assurance risks can affect SEHV system operation, availability, and performance.

Mitigation – Confirm information assurance guidelines are met to obtain accreditation for the SEHV system to operate within the SSC-A network infrastructure.

Risk Justification – Medium impact and low probability since information assurance audits can be performed prior to SEHV system deployment to meet accreditation standards.

4. Visualization change requests over time would affect SELI displays.

   Mitigation – SEHV displays should have the capability to learn, adapt or be easily modified.

   Risk Justification – Low impact and low probability since the SEHV system has not been developed yet.

5. Tools may produce similar data elements required for SELI trends.

   Mitigation – A tools analysis will have to be performed to determine which tool is the most appropriate to provide the needed data elements. A prototype can be produced to test operational functionality.

   Risk Justification – Low impact and low probability since a prototype can be developed to demonstrate system concepts and compare additional software tools for all 18 SELIs.

6. Tools may be subjected to manipulation where the SE / SE Management tools can only process the data entered versus validating the data entered.

   Mitigation – SSC-A will have to perform audits to validate information entered within SE / SE Management software tools.

   Risk Justification – Medium impact and medium probability since there may be a chance that false data is entered within the SE / SE Management software tools.

7. Software Tools may not be able to provide required data elements needed for SEHV trends.

   Risk Mitigation – Verify software tools can provide data elements needed for SEHV trends.

   Risk Justification – High impact with a medium probability because without the required data elements, SEHV trends will not be produced. Software tools identified within this report have the necessary data elements for trends; however, other SELIs may require unique data

elements that SE / SE management software tools cannot produce. This would result in a medium probability.

8. Data Elements from software tools may have to be translated into a compatible format for the SEHV analyzing capability.

   Risk Mitigation – Ensure data elements harvested from the software tools are in a format where storage and analytical functions for SEHV trending is in a compatible format.

   Risk Justification – High impact with a medium probability due to the need for data elements to produce SELI trends.

9. SE / SE Management COTS Software Tools may not provide data rights to distribute or assist with software code for data element capture efforts.

   Risk Mitigation – Contact commercial vendors to obtain information on costs, levels of support, and data rights information in regards to data elements for the SEHV system.

   Risk Justification – Medium impact with medium probability since SSC-A software engineers may be able to extract required data elements from SE / SE Management tools.

10. Not enough support to assist with Navy owned SE / SE management tools to provide data elements needed for SEHV trending displays.

    Risk Mitigation – Identify stakeholders that can provide direction for key personnel that can assist with technical support, and provide concurrence for the SEHV system effort.

    Risk Justification – Medium impact with medium probability since funding may be distributed in-house to support the SEHV system.

11. Upgrades to SE / SE management software may affect operation of the SEHV system.

    Risk Mitigation – Coordinate a process to receive information on upcoming updates for software tools to ensure updates to software do not affect the SEHV system. Create standard operating procedures for software upgrade verification testing.

    Risk Justification – Medium impact with a low probability since coordination for upgrade efforts can be defined prior to SEHV system development.

Table 19. Risk Table

Impact				
	High		**7,8**	
	Medium	**1,2,3,11**	**6,9,10**	
	Low	**4,5**		
		Low	**Medium**	**High**
	Probability			

THIS PAGE INTENTIONALLY LEFT BLANK

VII. CONCLUSIONS AND RECOMMENDATIONS

The work performed by the SEHV team will assist SSC-A 5.0 System Engineering Management in introducing a new automated method to capture the system engineering health of a project thus improving system engineering methodologies and efficiencies at SSC-A. Additionally, the SEHV team identified future research requirements and provided recommendations for SSC-A consideration.

A. CONCLUSIONS

SSC-A stakeholders recognize that a organizational SEHV automated capability is the way of the future. SEHV automated functionality is a leading edge process that has the potential to assist program managers, high level management, and decision-makers view a realistic status of a project and offer insight into determining whether projects have a high probability of failing. This insight gives the organization the ability to either add additional resources or stop spending additional dollars on a system that is being managed inefficiently. It can also show strengths and weakness of its existing workforce to determine new training workforce requirements. Currently, SSC-A monitors its projects via the traditional cost, schedule and performance indicators. It also processes its data calls through manual methods. The purpose of this capstone was to determine if an automated means of collecting and displaying SE data trends is feasible and effective. An architecture, acquisition and implementation strategy was proposed. To accomplish this, the SEHV team analyzed stakeholders' needs and requirements. A literature study was performed to gather what types of SELI should be analyzed per stakeholders' requirements. Modeling and simulation was performed to further analysis stakeholders' requirements as the SEHV team developed a model and simulated manual and automated data calls via "ExtendSim." These operational scenario use cases developed the SEHV IDEF0 documents via Innoslate, which consisted of five functional areas for analysis: Provide SEHV, Perform SE Activities, Provide SE Tools Functions, Maintain SEHV and Host SEHV. To accomplish the proposed automated architecture, the SEHV team performed an AHP to determine the best acquisition procurement strategy for moving

forward. From the results of the AHP, cost estimations were developed for the new automated architecture solution and compared to the existing manual system along with the associated risk analysis.

B. RECOMMENDATIONS

From this research process, the SEHV team made the following recommendations:

1. SSC-A should consider cost savings and operational efficiencies of switching from a manual architecture to an automated architecture to collect project system engineering health data.

2. SSC-A should consider an SEHV hybrid solution for their acquisition strategy for the automated architecture. This will consist of COTS and GOTS developed software. There are existing COTS SE software tools that can be leveraged as SSC-A will need to develop GOTS software solution for interfacing with the COTS tool and SSC-A's databases and government tools.

3. From the simulations, the SEHV team concluded that the performance of the current data call process is inefficient and needs the SEHV methodology to assist. Recommend usage of the system to include SE / SE management use of SE software tools at least once a month. This would satisfy the need for consistent and up to date data.

4. SSC-A should consider performing the proposed areas of future studies before implementing an automated SEHV system at SSC-A.

C. PROPOSED AREA OF FUTURE STUDIES

The SEHV team recognizes that there are several areas of future studies that SSC-A should consider before implementing the SEHV system into the organization. Due to capstone scheduling requirements, the SEHV team had to make several assumptions that reduced project scope and added risk considerations. Below is a list of potential areas for future study for SSC-A consideration.

- Continue the development of the SELI stakeholders' visualization requirements. SEHV team based stakeholders' requirements from the SSC-A CONOPS and IPT Handbook, which were validated by 5.0 competency management. These documents may be outdated or too broad

to capture all SSC-stakeholders requirements. The SEHV team recommends interviewing stakeholders which may provide additional requirements that were not mentioned in this document.

- SSC-A should form dedicated working groups with a variety of management positions to determine the types of visualization dashboards desired by the command to use.

- SSC-A should perform additional research on all leading indicators to determine the data elements that is needed by the SEHV system to provide the correct data visualization capabilities to the stakeholder. Due to time constraints, only five SELIs were selected for detailed analysis. All 18 SELIs require further research.

- SSC-A should consider performing additional research on existing SE tools to determine the interface requirements with the SEHV recommended architecture and existing database.

- As with any sensitive data, SSC-A should consider security policies that would need to be developed for authorization of storing, using and displaying the data.

- SSC-A should perform additional research on life cycle cost. The cost numbers, here within, were based off gathering requirements from SSC-A operational documents. These requirements will have to be revisited and that may affect cost. Also, additional market research is required for COTS SE tools. New stakeholders' requirements need to compare an analysis with existing COTS SE tools to determine if possible to use a COTS solution or if there is a need to develop GOTS solutions. Further studies will have to be put into place to see how much maintenance will be needed.

- SSC-A should consider developing quantitative mission of effectiveness values and run historical data through the SEHV ExtendSim existing models to gather this additional data. Due to time constraints and issues with collecting historical project data, the SEHV team could not run historical data through these existing models.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A. RISK SUPPORT

A. APPLICATION RISKS

The application risks are identified in Chapter VI, Section C, of the main body of this document.

B. SUGGESTED METHODS OF RESOLVING RISKS

Risks related to IT systems or applications were identified and documented based on the methodology in NIST SP 800–30, Risk Management Guide for Information Technology Systems. Table 20 identifies the Risk Management Roles and Responsibilities.

Table 20. Risk Management Roles and Responsibilities

Role	Responsibilities
Business SME (BSME)	The BSME assisted in identifying and determining the context, consequence, impact, timing, and priority of the risk.
Risk Manager or Project Manager (PM)	The Risk Manager or PM determined if the risk was unique, identified risk interdependencies across the project, verified if the risk was internal or external to the project, assigned risk classification and tracking numbers, and , continuously monitored the project for potential risks.
Integrated Project Team	The IPT was responsible for identifying the risks, the dependencies of the risk within the project, and the context and consequence of the risk. In addition, also responsible for determining the impact, timing, and priority of the risk as well as formulating the risk statements.
Risk Owner(s) (RO)	The Risk Owner determined which risks required mitigation and contingency plans; generated the risk mitigation and contingency strategies. The RO was responsible for monitoring, controlling and updating the status of the risk throughout this project.
Other Key Stakeholders	The other stakeholders assisted in identifying and determining the context, consequence, impact, timing, and priority of the risk.

C. MITIGATION EFFORTS FOR CAPSTONE PROJECT RISKS

Tools and Practices

A risk management log (RML) was maintained by the PM and RMGR and was reviewed as a standing agenda item for project team meetings.

Risk activities were recorded in the SEHV Risk Document located on the SEHV google shared drive.

Risk Closing

A risk was considered closed when it met the following criteria:

- Risk was no longer valid
- Risk Event had occurred
- Event was no longer considered a risk
- Risk closed at the direction of the PM

Lessons Learned

The lessons learned were captured and recorded in the SEHV risk assessment folder located on google docs. Table 21 and 22 displays the program risk rankings.

Table 21. Program Risk Ranking

How to Rank Program Risks
Individually rank each risk identified according to its frequency/likelihood and its severity.
Enter information into white cells. Shaded cells will calculate automatically.
Step 1 – Rank the frequency/likelihood of a given risk from 1 to 4 using these criteria:
4 = Very Likely - Almost certain to occur over the life of the project (or a 10 year period—whichever is shorter)
3 = Likely - Probably will occur during a 10-year period
2 = Unlikely - Probably will **NOT** occur during a 10-year period
1 = Very Unlikely - Almost certain **NOT** to occur during a 10-year period

Step 2 – Rank the severity of a given risk from 1 to 4 using these criteria:
4 = Very High – Would prevent goals and objectives from being achieved
3 = High – Would cause significant problems or delays in objectives being achieved
2 = Medium – Would cause relatively minor problems or delays in objectives being achieved
1 = Low – Would probably not affect project implementation
Step 3 – Compute the average frequency/likelihood and average severity ranking for each risk category.
The risk assessment tool will calculate and display these averages automatically.
Step 4 – Add the average frequency/likelihood and severity ranking for each risk category.
The risk assessment tool will calculate and display these sums automatically.
Step 5 – Determine whether each risk category is high, medium, or low according to the following thresholds:
9-12 High Risk (red) – You should have a detailed mitigation action and perhaps consider modifying your goals and objectives
4-8 Medium Risk (yellow) – You should have a clearly defined mitigation action
1-4 Low Risk (green) – No mitigation action required (or a very basic action if you think it is necessary)
The risk assessment tool will determine and display whether each risk is high, medium or low automatically.
High risks categories will automatically turn cells red, medium risks will automatically turn yellow, and low risks will automatically turn green.
How to develop Risk Mitigation Actions
For risks that are essentially internal (e.g. Capacity, Leadership, Partners) focus on ***taking action to reduce the risk***.
For risks that are external to the project (e.g. Political, Economic) response will more likely be to ***develop contingency plans and monitor the risks***.
Risk mitigation strategy should be simple, clear and manageable with the resources available.

Risk	Potential Impact on Capstone Report 1/2/3/4	Potential Impact on Project/IPR Success 1/2/3/4	Likelihood of Occurrence 1/2/3/4	Score 1 Through 12	Ranking L/M/H	Mitigation Plan strongly recommended for H/H, H/M and M/H Possibly even M/M
1. Develop Chapter 1 project report	2		1	3	L	M/L
2. Develop IPR practice 1 slides		3	1	4	M	M/L
3. Get Approval of PMP (High Risk)		4	2	6	M	H/M Keep working with advisors until we get a signed document
4. Get Proposal Approved (High Risk)	4	4	2	10	H	H/H/M Keep working with advisors until we get a signed document
5. Ensure research question or developed	2		1	3	L	M/L
6. Failure to Ensure OV-1 complete (DONE)		1	1	2	L	L/L Completed
7. Failure to deliver SEHV context Diagram		4	L	4	M	H/L
8. Understanding stake holders needs (base-lining Requirements)	4	4	2	10	H	H/H/M Continue to work with (SPAWAR) stakeholders until requirements are base lined
9. Scoping system requirements (ensure project does not become to large)	4	4	3	11	H	H/H/M Continue to work with (SPAWAR) stakeholders to ensure they understand the scope of this project
10. Keeping system requirements within scope (preventing Scope creep ensuring that one requirement does not get to big to handle)	4	4	3	11	H	H/H/M Continue to work with (SPAWAR) stakeholders to ensure they understand the scope of each requirement
11. Ensuring requirements are understood by stakeholder	3	3	1	7	M	H/L Continue to work with advisors until all stakeholders understand scope of the project
12. PMP refinement	3	3	2	8	M	H/M Keep working with advisors until we get a signed document

13. Only deliver what is in CONOPS	3		2	5	M	H/L Keep track what will be delivered
14. WBS w/PMP		2	2	4	M	M/L Completed
15. Update WBS w/ PMP if changes occur		2	2	4	M	M/M ensure version control used in Goggle DOCS
16. SELI version 2		2	1	3	L	M/L Completed
17. Update SELI when necessary		1	1	2	L	L/L 18 SELIS are set, however, need to keep track through version control
18. Submit requirement to NPS professor's		2	1	3	L	M/L
19. Decomposed SE processes		2	1	3	L	M/L
20. List of stake holders (grouping)		2	1	3	L	M/L
21. PITCO what does it actually mean is it risk with the project of risk with cost and performance. How do we actually determine which risk to use base on INCOSE SELI risk trends	4	4	4	12	H	H

Table 22. Additional Risks

Risk Factors	Low	Medium	High	Mitigation Ideas
1) Project Size (Duration or Effort)	< 4 Months or < 1000 Hours	4-6 Months or 1000 to 3000 Hrs	> 6 Months or > 3000 Hours	● Decomposition (Break into smaller phases) ● Phased implementation
2) Project Scope	Defined and Not Large or Complex	Somewhat Defined/ Large/ Complex	Not Defined or Large/Complex	● Decomposition ● Add another analysis phase ● Detailed specifications ● Early prototype/review of functionality ● Add more time to the project schedule.
3) Project Decision-Making	One sponsor & One	Sponsoring/ Decision making	No Clear Sponsor/Decision-maker	● Specify decision-makers' role in project

	decision-maker	committee		documentation ● Add tasks to the Project Plan for involving decision-makers and managing relationship with them
4) Environmental State (Software/Hardware/Network)	Stable / Little Change Required	Transitional with Some Changes	Volatile or Yet to be Deployed	● Additional testing, particularly stress testing ● Training on new environment ● Find other projects using a similar environment to compare notes ● Get a prototype deployed ASAP on new environment
5) Team's Experience (with environment/project size/scope)	Extensive (2 or more similar projects)	Moderate (at least one similar project)	Limited (No similar project completed)	● Additional team training ● Cross-training ● Consider hiring consultant with additional experience for initial period
6) Impact on other CDL Operations	None or Very Little	Some Change	Extensive Changes	● Additional User Training ● On-site assistance for cutover period ● Phased cutover ● Expose key stakeholders to prototype early
7) Project Schedule created by:	Project team with standard estimation methods	Project team using some rough guesses based on limited info.	Mandate from an external source	● Supplement resources (outside consultants, other groups) ● Try to reduce scope of deliverable. ● Is there a minimum level of functionality for the mandated delivery date? ● Add time to the schedule to allow for slippage.

APPENDIX B. SEHV PROJECT MANAGEMENT PLAN

Project Management Plan (PMP)
for the
Systems Engineering Health and Visualization (SEHV)
Capstone Project

SEHV-PMP-0001
Version 0.5
04June14

Prepared by:
SEHV Capstone Project Team

Chester Alonzo
Michael Besco
Theresa Inman
Michael Jourdain
Regina McNeil
Clive Sugama

Approval Sheet

For

SEHV Project Management Plan

Submitted by

X

Clive Sugarra
NPS MSSE Cohort 311-132W Capstone Project...

X

Chester Alonzo
NPS MSSE Cohort 311-132W Capstone LSE

X

Michael Besco
NPS MSSE Cohort 311-132W Capstone Data A...

X

Theresa Inman
NPS MSSE Cohort 311-132W Capstone Softwa...

X

Michael Jourdain
NPS MSSE Cohort 311-132W Capstone Cost E...

X

Regina McNeil
NPS MSSE Cohort 311-132W Capstone Editor-...

Advisors Approvals

X

Dr. Rama Gehris
MSSE Cohort 311-132W Capstone Advisor

X

Prof. Bonnie Young
MSSE Cohort 311-132W Capstone Advisor

MSSE Dept. Approvals

X _____

Name
MSSE Academic Associate

X _____

Name
SE Department Chair

Record of Changes

***A –** Added **M –** Modified **D –** Deleted

Change Number	Date	Number of Figure, Table or Paragraph	*A M D	Title or Brief Description -	Change Request Number
1	3/16/2014	Entire Document	A	Initial version of the SEHV PMP	
2	04/03/2014	Entire Document	M		
3	4/14/2014	Entire Document	M	Change to new proposal	
4	4/25/2014	Entire Document	M	Edited Full PMP for submission - rmcneil	Approved
5	5/5/2014	Entire Document except for Appendices A, B, C, & D	M	Modified per change recommendations	
6	5/5/2014	Figure 1	A	Aggregated Architecture by Modus 21	
7	5/6/2014	Entire Document	M	Edited for formal submission - rmcneil	Approved
8	5/18/2014	Tables A-1, A-2	D	WBS and Work Products Appendices	
9	5/21/2014	Entire Document	M	Edited for formal submission -rmcneil	Approved
10	6/04/2014	ToC, List of Figs. & Tables, Sections 1.3, 3, Refs. Added new Figure	A, M, D	Edited for formal submission - rmcneil	Approved

Table of Contents

1. INTRODUCTION....144
- **1.1 PMP PURPOSE....144**
- **1.2 PROBLEM STATEMENT....144**
- **1.3 PROJECT BACKGROUND....144**
  - **1.3.1 Literature Review....146**
- **1.4 PROJECT OBJECTIVES AND PROJECT SCOPE....147**

2. PROJECT ORGANIZATION & MANAGEMENT....151
- **2.1 TEAM ROLES & RESPONSIBILITIES....151**
- **2.2 STAKEHOLDERS....153**
- **2.3 PROJECT MANAGEMENT....153**
  - **2.3.1 Project Monitoring & Control....154**
  - **2.3.2 Requirements Management....154**
  - **2.3.3 Schedule Management....154**
  - **2.3.4 Quality Management....155**
  - **2.3.5 Communications Management....155**
  - **2.3.6 Risk Management....155**
  - **2.3.7 Configuration Management....156**

3. SYSTEMS ENGINEERING APPROACH....157
- **3.1 PROBLEM DEFINITION/NEEDS ANALYSIS....160**
- **3.2 REQUIREMENTS ANALYSIS/METRICS ANALYSIS....160**
- **3.3 FUNCTIONAL ANALYSIS....161**
- **3.4 SYSTEM ARCHITECTURAL MODELING....161**
- **3.5 SYSTEM ANALYSIS....162**

4. PROJECT MILESTONES & DELIVERABLES....163
- **4.1 SCHEDULE....163**
- **4.2 PROJECT REVIEWS....166**
- **4.3 DELIVERABLES....166**

APPENDIX A ACRONYMS AND ABBREVIATIONS....168

APPENDIX B SEHV CAPSTONE PROJECT TOOLS AND PLANS....170

APPENDIX C GLOSSARY....171

APPENDIX D LIST OF FIGURES AND TABLES....172

REFERENCES....173

1. INTRODUCTION

1.1 PMP PURPOSE

This document is the Project Management Plan (PMP) for the System Engineering Health and Visualization (SEHV) Capstone Project, Naval Postgraduate School (NPS) 311–132W Master of Science in Systems Engineering (MSSE) / Master of Science in Engineering Systems (MSES) Program. This SEHV Capstone PMP serves as the top-level planning document for the project. All activities and processes performed for the SEHV capstone project shall be in accordance with this plan. This PMP also describes the SEHV capstone project organization and documents roles and responsibilities. The specific objectives for this document include documentation of the tools, techniques, and methodologies to be used to support SEHV capstone project management and execution. The intended audience of the SEHV Capstone PMP includes the primary stakeholders for project execution purposes, NPS advisors, and other stakeholders for content awareness.

1.2 PROBLEM STATEMENT

SPAWAR Atlantic (SSC-A)'s 5.0 leadership does not have adequate visibility into the Systems Engineering (SE) health of its programs in order to make timely and accurate decisions concerning potential program risks and/or possible mitigation strategies. SSC-A currently performs manual data calls to obtain information required to assess a project's current state of systems engineering health. SPAWAR leadership also lacks a means to measure the quality of SE work for the projects and programs being executed at the command. With an ability to access, store, and analyze the right program information, leadership could gain insight into potential systems engineering risk areas in order to be proactive instead of reactive to issues that lead to program failures or reduced capabilities. This capstone team will develop a conceptual design and model of a SEHV capability to provide SSC-A leadership with insight into the SE health of its programs.

1.3 PROJECT BACKGROUND

SSC-A strives to provide continuous process improvement when providing quality systems to stakeholders. The goal to be more proactive with the identification of system health indicators, during earlier phases of system development, matured as system failures were often realized after the fielding and operational delivery. The savings for early identification and monitoring of system health can be realized in the next examples. The Defense Information Management Human Resource System (DIMHRS) is a failed project that did not have proper insight into SE health issues. Almost 1 billion dollars was spent on DIMHRS and still the project failed to deliver the capability promised. The deliverables were supposed to be used across all Department of Defense (DOD) branches

of service but ended up only being used by the Army and Air Force. The Army and Air Force are currently experimenting with some of the units that were delivered. The lack of written requirements and configuration management were major contributors to the issues with DIMHRS. Leadership of DIMHRS directed engineers, on several occasions, to develop the project and forego the documentation until later. Each branch of service wanted it tailored to suit their needs which fueled unrealistic schedules and continuous requirement changes. The resulting outcome of the DIMHRS project came nowhere near the overall expectation. (Ugone 2010)

SSC-A has developed human resource systems, such as the Navy Standard Integrated Personnel System (NSIPS), the Career Information Management System (CIMS), and the manpower control system, Total Force and Fleet Manpower System (TFFMPS), which span the complete software development life cycle from conception to sustainment. SSC-A has also developed the Veteran Affairs' (VA) Veterans Relationship Management/ Customer Relationship Model (VRM/CRM) and a Master Veteran Index (MVI) system and has integrated these systems with numerous other legacy VA systems. There are several other projects that are in progress that include concept refinement, development, integration, and potentially sustainment of software that are within different stages of the project life-cycle. The SEHV solution needs to provide the ability for each individual project to explain its own unique representative systems engineering status in order for automated analysis of project health to be identified and visualized to command leadership.

Utilizing the data housed in SSC-A's existing System Engineering (SE) toolsets would only provide a snapshot of the status of the project at the moment in time when the request of the data is conducted. SSC-A does not have visual trending representations of measured SE / SE management processes that can provide visibility into expected project performance and potential future states. Dynamic data will need to be captured, stored, compiled, and analyzed from the workforce in an automatic or non-disturbing fashion to display the most current status. The SEHV team will research different visual depiction capabilities available to illustrate the measures extracted from projects in order to provide SEHV stakeholders indicators of potential project failure.

The SEHV capability is needed to save time and cost in the effort to work more efficiently. Manual data calls, meetings, and other grueling efforts to provide information to leadership is an ongoing struggle at SSC-A. Currently leadership manually conducts data calls to obtain necessary SE / SE Mgmt. information. The information requested trickles down to lower echelons and ultimately to the System Engineer. Although the System Engineer performs their daily activities, they have to make time to provide information requested by leadership. At times, the System Engineer does not have time to

respond in a timely manner. This takes quite a bit of time when there are multiple projects from which to collect data. An individual actually has to track the information requested from each project, and analyze this information to ensure this is the correct data leadership is requesting. Figure 1 shows the SSC-A current state (without SEHV) OV-1 diagram.

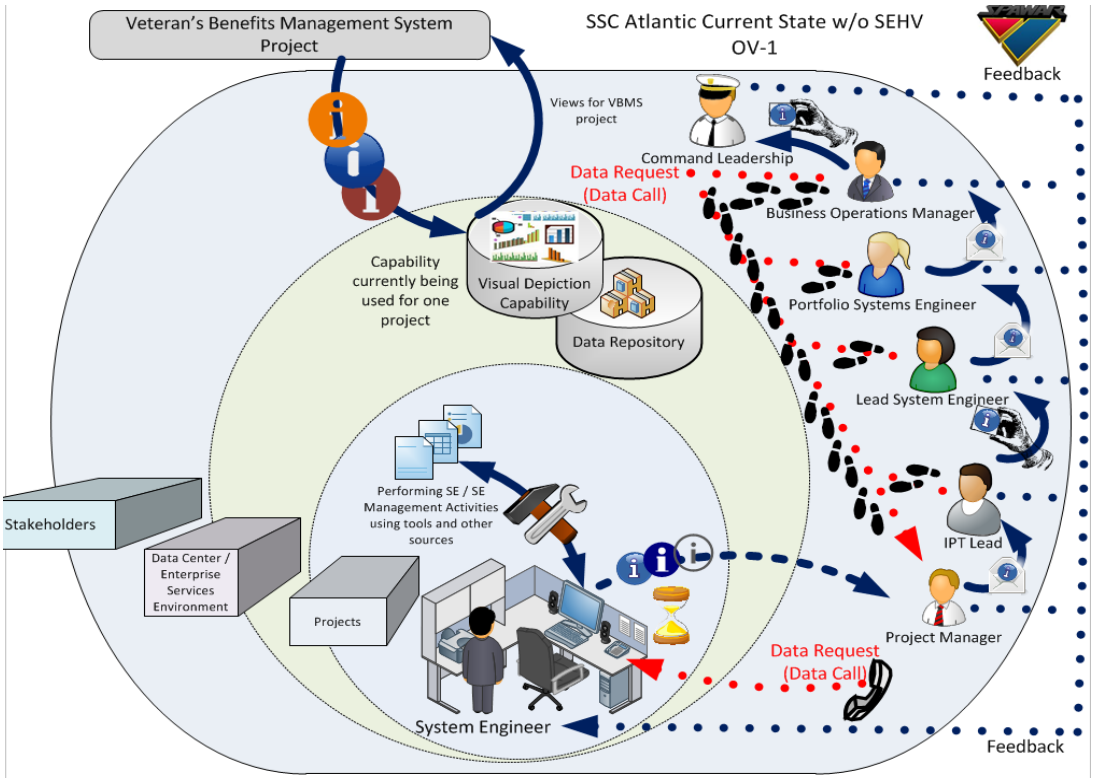


Figure 1 SSC-A Current State w/o SEHV OV-1

1.3.1 Literature Review

Literature review was conducted and promoted the use of International Council on Systems Engineering (INCOSE) Systems Engineering Leading Indicators (SELI) Guide version 2.0. The team's initial research consisted of exploring and reviewing different organizations' / institutions' publications, briefs, specifications and artifacts. The team's initial review provided insight on how SE metrics are currently being utilized and what information is being revealed.

MIT previously conducted research to determine how to use SE metrics to identify problem areas and to predict trends. The study breaks down characteristics of what

constitutes a leading indicator and its specific usefulness. Objectives and goals were also contained within the document. (Rhodes, Valerdi and Roedler 2008)

Paul Montgomery and Ron Carlson provided in an NPS literary work on April 30, 2010, a discussion about the Applied Leading Indicators (ALI) SE tool. Data analysis features were illustrated that Naval Air (NAVAIR) used for their SE process areas. Historical metrics were obtained and analyzed to support the goal of predicting future performance. (Montgomery and Carlson 2010)

INCOSE's technical product identified leading indicators that were associated with various parts of the project life cycle, and include work from reputable sources such as the Massachusetts Institute of Technology (MIT), Lockheed Martin Corporation, INCOSE, the Lean Aerospace Initiative, the Systems Engineering Advancement Research Initiative, and Practical Software and Systems Measurements (PSM). Trends and various measurements were defined within the technical product to provide examples of needed metrics. The ALI tool was briefly discussed and its capabilities/limitations were clearly defined. (INCOSE et al. 2007), (INCOSE et al. 2010)

1.4 PROJECT OBJECTIVES AND PROJECT SCOPE

The objective of this Capstone Project is to develop the requirements, architecture, data strategy, and conceptual model for the SEHV capability. The team will develop SE health metrics by analyzing the SEHV requirements and studying SE metrics developed by other organizations, such as the INCOSE SELI. The team will identify what data and information from SSC-A programs is required for the SEHV capability to perform its health analysis. The current state of data collection within the organizations (including level of automation) will be documented. The information on what is currently being collected and how effectively and efficiently the collection is being done will be used to analyze the feasibility and costs of any proposed SELI visualization and inform the final recommendations outlined in the Capstone final report. The team will analyze stakeholder needs which will drive requirements and capability development. The team will also determine what types of information need to be visualized to best meet stakeholder needs.

The SEHV capability context diagram illustrates a simplified diagram of the proposed SEHV capability. Projects would be the source for the data elements for both the SE / SE Mgmt. data elements. SE / SE Mgmt. tools or other sources will be used to generate these data elements. The SEHV capability that is housed within the DC/ESE will use the concepts of the INCOSE SELI Guide v2.0 to display views to SEHV stakeholders. The stakeholders would be able to review these SELI trends from data collected from projects and provide feedback. Figure 2 shows the SEHV Capability Context Diagram.

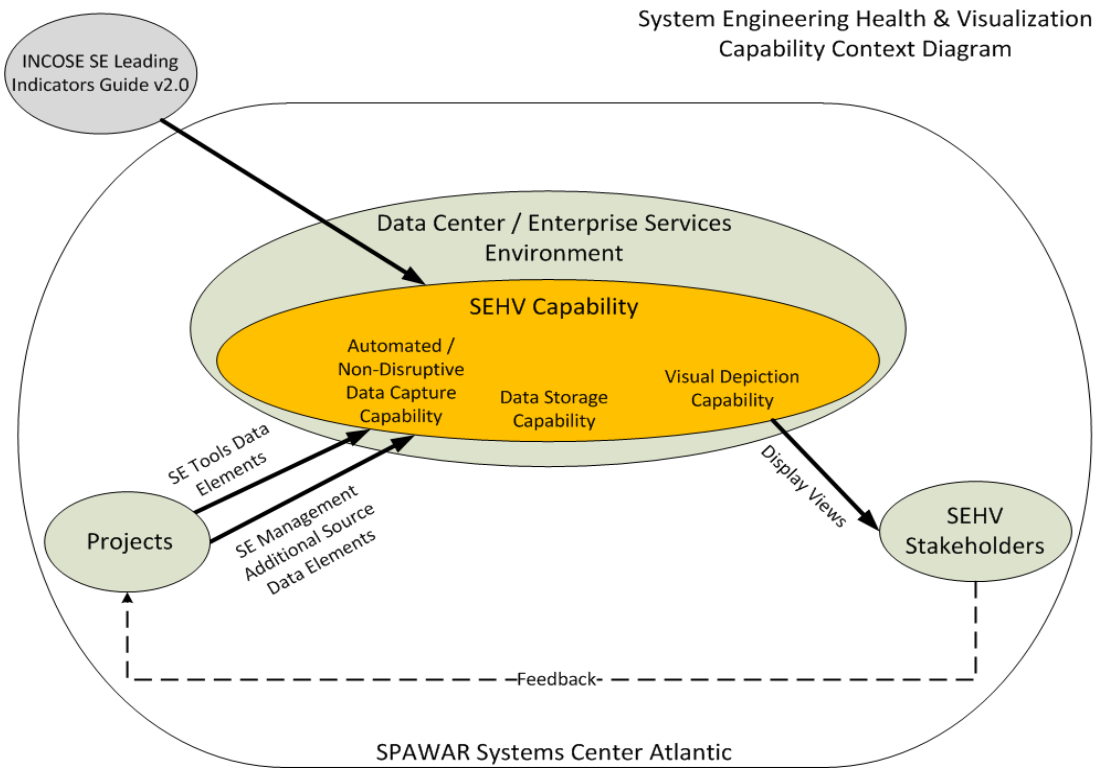


Figure 2 SEHV Capability Context Diagram

Figure 3 shows the OV-1 which illustrates the SEHV capability. The data source will be produced by the system engineer allocated to a project. The system engineer will perform SE / SE Mgmt. activities using tools and other sources. The data elements from these tools / other sources will be harvested or collected by non-disruptive means to be kept in the data repository located within the Data Center / Enterprise Services Environment (DC/ESE) at SSC-A. The VBMS project has a Visual Depiction Capability and Data Repository within the DC/ESE which can be leveraged for the SEHV capability. This capstone project will research means to utilize these capabilities to the fullest when introducing the SEHV capability. An SELI analyzing capability will have to be introduced to work with the data repository in order to produce data schemas for the visual depiction capability. The visual depiction capability will provide displays of SE health to SEHV stakeholders in order to initiate and facilitate feedback to the system engineer of a project.

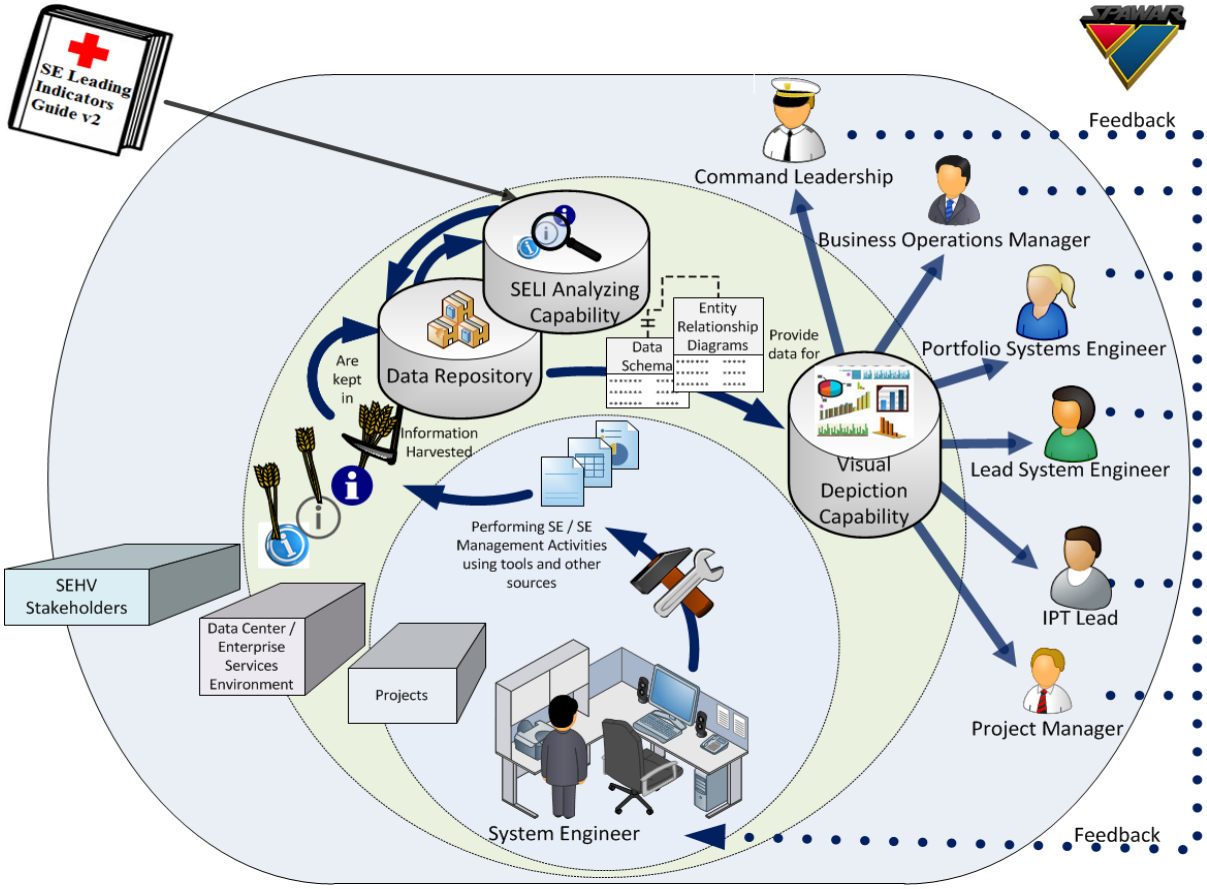


Figure 3 SEHV Capability OV-1

Key SE health metrics provide insight into the quality and effectiveness of SE activities which will support command objectives of consistent solution delivery and customer satisfaction. Functional and physical architectures will support a depiction of the collection, evaluation, and dissemination of relevant dynamic data elements that support the validated SELI measures. This architecture must also support temporal and pattern analysis of the data elements. A method to ingest the identified data elements into the SEHV data repository, in an automated manner, will also need to be included. The frequency with which the data is pulled from the various SE toolset data sources and ingested into the SE health data repository will have to be determined. The combinations of data elements and collection processes will be evaluated by modeling and simulating the proposed SEHV architecture to identify patterns and trends from historical project data and determine how the solution supports the prediction of good and bad project outcomes based on SELI established criteria. The output of the project should provide a package of technical work which will clearly characterize and describe elements necessary to realize an automated SEHV capability. Characterizing SSC-A key

stakeholders, prioritizing and analyzing user requirements, exploring feasibility and unity of SELI measures, developing architecture, and compiling a description of required components will be within the scope of this project. The SEHV data strategy, data repository requirements, and technical requirements will be developed to characterize the desired SEHV capability. Cost analysis will be performed to determine affordability as a factor to the overall SEHV solution.

2. PROJECT ORGANIZATION & MANAGEMENT

2.1 TEAM ROLES & RESPONSIBILITIES

Figure 4 provides the high-level organizational structure chart for the SEHV Capstone Project.

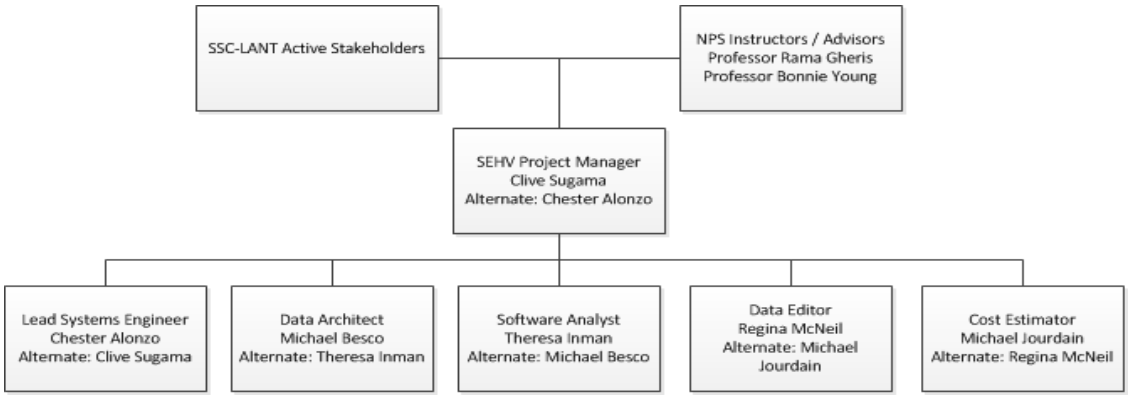


Figure 4 SEHV Capstone Project Organizational Structure

The SEHV team will be organized according to key activities necessary for completion of the project. The team will have a primary and alternate to support these key activities. The key activities for this project are project planning, requirements development / validation, mapping of tools, requirements / metrics analysis, cost estimation, process modeling, risk assessment, identification of use case scenarios, and an analysis of proposed metrics and process sets. The capstone advisors will review the scope, organization, quality, schedule of the project and provide feedback on a regular basis. The team will engage with the stakeholders to identify use cases, requirements and their priorities. Table 1 lists the SEHV team roles and responsibilities and identifies each team member(s) assigned.

Table 1 SEHV Capstone Project Team Roles and Responsibilities

Team Member	Roles and Responsibilities
Project Manager and Project Technical Risk Analyst - Primary-Clive Sugama Alternate-Chester Alonzo	The Project Manager (PM) role is responsible for the planning, monitoring, and controlling activities of the project. The PM will take the lead on developing the PMP. The PM will also take on the duties for Project / Technical Risk Analyst and Configuration Manager (CM). The PM will also assist with identifying key stakeholders and will facilitate discussions with stakeholders for the purpose of capturing requirements, use cases, and metrics needs.
Lead Systems Engineer (LSE) - Primary-Chester Alonzo Alternate-Clive Sugama	The LSE will take the lead on the elicitation, documentation, and organization of the stakeholder requirements. The LSE will capture system use cases from the various stakeholders. The LSE will also track and manage the interfaces for the architecture. Finally, the LSE will track and manage the activities performing the verification and validation of the architecture.
Data Architecture Lead - Primary-Michael Besco Alternate-Theresa Inman	The Data Architecture Lead will take the lead on the architecture for the system. The data architect will take the lead in identifying leading indicators that would indicate the health of system engineering efforts within SSC-A. Additionally, the data architect will develop the entity-relationship architecture from the SE tools that will map data to the leading indicators.
Software Analyst - Primary-Theresa Inman Alternate-Michael Besco	The Software Analyst will analyze the implementation of the architecture. The Software Analyst will interface with the Architecture Lead from SSC-A Enterprise SE Tool Suite group to determine the information needed for the architecture from the selected tool suite and recommend how to automatically collect it. .
Data Editor - Primary-Regina McNeil Alternate- Michael Jourdain	The Data Editor will ensure all documentation is formatted, consistent, and contain information pertinent to that deliverable. The Data Editor will enforce the standards set by the NPS Thesis Processing Office on the SEHV project report.

Cost Estimator - Primary-Michael Jourdain Alternate-Regina McNeil	The Cost Estimator will provide cost and benefit analysis on the SEHV capability recommendation. The Cost Estimator will also analyze costs associated with implementation of metric data collection and provide cost projections associated with SEHV development.

2.2 STAKEHOLDERS

Table 2 Stakeholder Roles and Responsibilities

Stakeholder	Roles and Responsibilities
Advisors - Professor Young / Profes Gehris	The advisors will review deliverables and documents to ensure it meets both writing and content related NPS standards before they are passed onto the department for concurrence. The advisors will guide the SEHV project team on the right path to a successful capstone project. Assistance with project material and mentoring will be provided. Clarifying questions asked by the SEHV team will be addressed by the advisors. Advisors will also act as a liaison between the students and the SE Department.
SSC-A Active Stakeholders -	The SSC-A active stakeholders will provide appropriate resources to support the SEHV project. The SSC-A active stakeholders will also participate in SEHV project meetings to be informed about project progress, status and risks.
SSC-A Projects Group (Passive Stakeholders) Information Producing Grou	The SSC-A Projects Group (passive stakeholders), within the command, will generate data automatically or through non-disruptive means to the SEHV project solution. Data elements will be stored and displayed for trend analysis. SSC-A projects will be able to assess their SE health from the resulting display.
SSC-A Leadership (Passive Stakeholders) Information Consumer Grou	The SSC-A Leadership (passive stakeholders) within the command will view trending information from the SEHV project solution. The stored data will be displayed for trend analysis. SSC-A Leadership will be able to assess and provide feedback to projects in regards to SE health.

2.3 PROJECT MANAGEMENT

This PMP will be used to manage project effort, schedules, risks, and other relative project elements. All SEHV Capstone Project documents will be maintained in Google Docs, and will be used to provide configuration management and version control. SEHV Capstone Project Close-Out will include finalizing the Capstone Project final report prior to the end of the final NPS quarter. A final IPR will be conducted with stakeholders and NPS Advisors (and other NPS Faculty, as appropriate) to support the SEHV Capstone Project close-out.

2.3.1 Project Monitoring & Control

The SEHV Capstone PM will ensure the SEHV Capstone Project's progress meets the required due dates. Appropriate actions can be taken when the project's performance deviates significantly from the plan. The SEHV Capstone PM will monitor the project against the plan by keeping track of project milestones. Project risk will also be monitored to identify potential road-blocks during the capstone project time frame. Stakeholder requirements will be mapped within the Innoslate tool for requirements analysis. Progress reviews will take place during the time-slotted IPRs.

2.3.2 Requirements Management

The SEHV Capstone PM will manage the requirements of the SEHV Capstone Project products and product components, and will ensure alignment between requirements, SEHV Capstone Project plans, and work products. In managing these requirements, the PM will ensure documenting SEHV Capstone Project processes for interpretation, agreement, and commitment to functional requirements. The SEHV Capstone Project requirements will be traceable within Innoslate. Requirements documentation, traceability, and addressing changes will take place within Innoslate. IPRs, and other mechanisms necessary to ensure that inconsistencies between requirements, project plans, and work products are identified, tracked, and resolved, will be conducted.

Requirements are documented in Innoslate to facilitate tracking and change impact analysis. As requirements evolve, traceability is maintained. Requirements are reviewed internally during weekly meetings, where inconsistencies and issues are identified to be either resolved or escalated for resolution. The requirements document identifies when requirements are formally base lined and subject to formal configuration control. Prior to that point, the SEHV Capstone PM shall set and maintain informal requirements configuration controls within Innoslate. Requested changes to requirements are documented and reviewed for technical and management impacts. Approved changes are implemented and tracked after the SEHV team and advisors agree on a decision.

2.3.3 Schedule Management

The SEHV Capstone Project schedule baseline is captured in Table 5. Specific deliverables will be assessed at the end of each NPS Quarter by the NPS instructors. Actions will be taken on major deviations from the baseline schedule in order to meet specified schedule and performance measures. Scheduled baseline changes will be documented and retained for the life of the project.

2.3.4 Quality Management

Quality management will be adhered by the advisors reviewing the SEHV work products. IPRs, and any other beneficial reviews deemed necessary, take place to assess the overall quality of the SEHV project. The SEHV team will make adjustments, as required after each review, to satisfy NPS requirements and meet project milestones.

2.3.5 Communications Management

The SEHV Capstone Project requires continuous, predictable communications. Table 3 show the SEHV communication protocol.

Table 3 Communications Management

Audience	Media	Purpose	Topics	Frequency
SEHV Capstone Project Team	DCO, L Meetings	SEHV Team Advis Comment Adjudication a Strategy Sessions	Advisors Comments, Updates, Brainstorming	Weekly (Tuesday)
SEHV Capstone Project Team, SSC-A Active Stakeholders	DCO, Email	SEHV Capsto Project SSC Atlantic Meeting	POA&M, Action Items	Weekly (Friday)
SEHV Capstone Project Team, NPS Advisors	Blackboard, Email	Project Reviews	Progress, Findings, Potential Issues	Weekly (Friday) Quarterly
SEHV Capstone Project Team, SE Process Subject Matter Experts (SME)	Live Meetin Email	SE Leading Indicato Discussion	SE Proc Measures, Outcomes	Weekly
SEHV Team,	Live Meetin	Visualization	Visualization	Weekly

Visualization SME's	Email	Strategy	Alternatives, Methodology	

2.3.6 Risk Management

There are two kinds of risks associated with the SEHV Capstone: technical (risks to the proposed solutions) and project risks (risks to capstone project completion). These risks will be tracked separately. Technical risks are documented (and may be revised as new information arises) and will appear in the final report. Project risk will follow the SE approach described in Section 3 and will not appear in the final report.

Risk Management will be executed throughout the life of the SEHV Capstone Project. This is a critical step in clearly defining risk thresholds. Risks will be managed using the risk tracker within Google Docs. SEHV Capstone active stakeholders, the SEHV team, and the NPS advisors will review risks as they arise in regards to schedule and performance, and then develop the appropriate mitigation strategy and activities to reduce and/or eliminate these risks. Risk reviews will be conducted on a weekly or monthly basis, depending on the severity and impact of identified risks.

2.3.7 Configuration Management

The SEHV Capstone PM, and the Configuration Manager (CMgr), will ensure CM is executed throughout the life of the SEHV Capstone Project. CM will include the use of Google Docs to ensure team collaboration on SEHV capstone project documentation. Google Docs will serve as the repository for the SEHV capstone project and provide the capability to audit document modifications and team member ownership of the change. Document review will be conducted via email and/or Sakai between the SEHV team and NPS advisors.

3. SYSTEMS ENGINEERING APPROACH

The SEHV team will analyze SE leading indicators to facilitate project risk identification. The team will study the INCOSE SELI Guide version 2.0. This guide will be used as a control for this project. This guide identifies 18 leading indicators that provide consistent insight into future project performance. The use of the SELIs will ensure levels of quality for the solution. SELIs will be reviewed and assigned priorities based on their impact to project cost and schedule, and system performance as well as their ability to answer common questions by engineering managers concerning system risks. Table 4 shows the SELI measures that were obtained for trends.

Table 4 SELI Trends

SELI 1. Requirements Trends
SELI 2. System Definition Change Backlog Trends
SELI 3. Interface Trends
SELI 4. Requirements Validation Trends
SELI 5. Requirements Verification Trends
SELI 6. Work Product Approval Trends
SELI 7. Review Action Closure Trends
SELI 8. Technology Maturity Closure Trends
SELI 9. Risk Exposure Trends
SELI 10. Risk Treatment Trends
SELI 11. Systems Engineering Staffing and Skills Trends
SELI 12. Process Compliance Trends
SELI 13. Technical Measurement Trends
SELI 14. Facility and Equipment Availability
SELI 15. Defect and Error Trends
SELI 16. System Affordability Trends
SELI 17. Architecture Trends
SELI 18. Schedule & Cost Pressure

The SEHV team will down select SELI based on criteria such as SELI mapped to multiple stakeholders, automated method of capturing information, tools that produce data elements that are needed from SELI, existing / available SE / SE MGT tools, and the cost of tools / software. The data collection process of the SELI choices will provide an automated solution that harvests SELI measures needed to indicate project risk areas that lead to project failure. Once data is collected display mechanism options will need to

be researched to be able to display trends of SELI measures. Figure 5 shows the SEHV project approach.

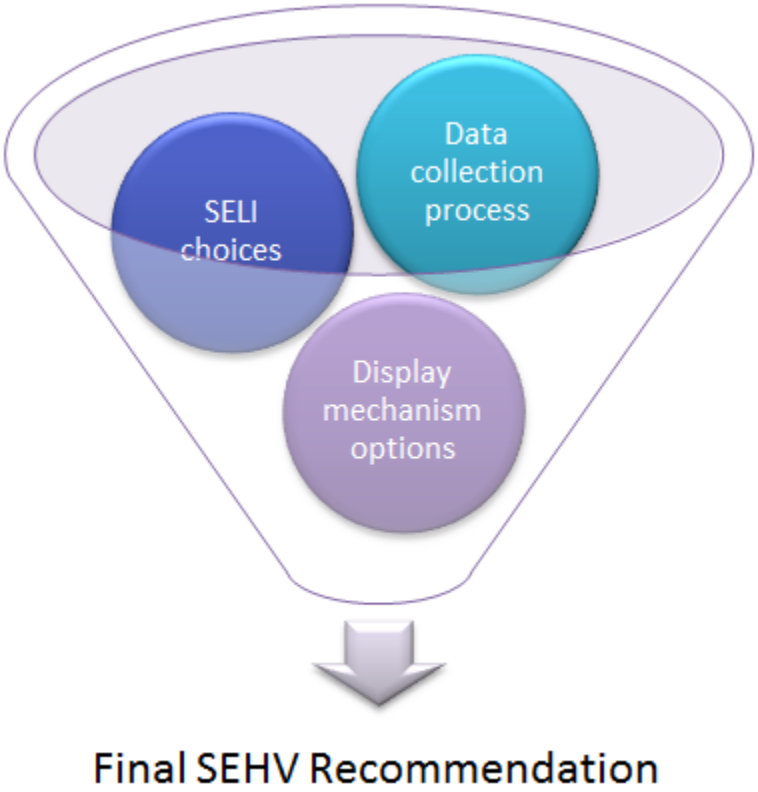


Figure 5 SEHV Project Approach

The SEHV team will utilize an SE approach derived from the IEEE 1220_2005 Systems Engineering Process. This process is appropriate to use for this project since this approach produces documents / models vice hardware or software. Using this process will help facilitate the project's expected process environment, interfaces, work products, and necessary SE tools needed for the SEHV capability. This process will begin by obtaining SSC-A stakeholder inputs, then going through the SEHV SE process, and ultimately ending up with a recommendation (based on weighted criterion) of SELI choices that describe data measure collection methodologies with their respective display mechanisms. Figure 6 shows the SEHV SE process.

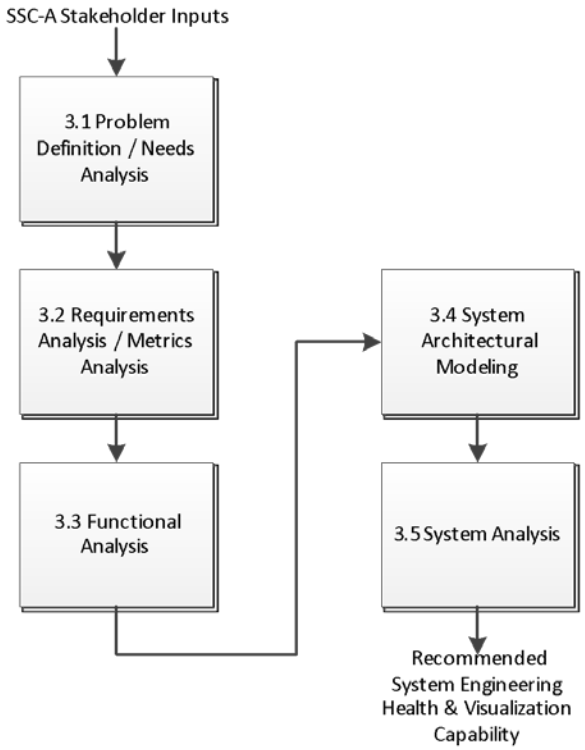


Figure 6 SEHV Systems Engineering Process

The SEHV team will conduct a literature review to research how other organizations perform SEHV processes, including which SELIs and supporting metrics were used. The team will perform a requirements analysis to establish a set of requirements for the SEHV system and will define operational scenarios. The team will develop functional and physical architectures that will support the operational scenarios to evaluate alternatives through modeling and simulation. The analyses results will form the basis of the team's recommendation to stakeholders.

The team will provide requirements and concept of operation information that will be included in the final report. The team will also identify and address risks to implementation, define mission success requirements, develop preliminary architectures, develop use cases, perform model-based systems engineering, process analyses, and communicate status to project sponsors. An investigation of current tools, application effectiveness, gaps within current tools, and potential trade space between collection efforts, cost, and value provided to the user will also take place. Figure 7 shows SEHV process diagram where the SEHV team will implement.

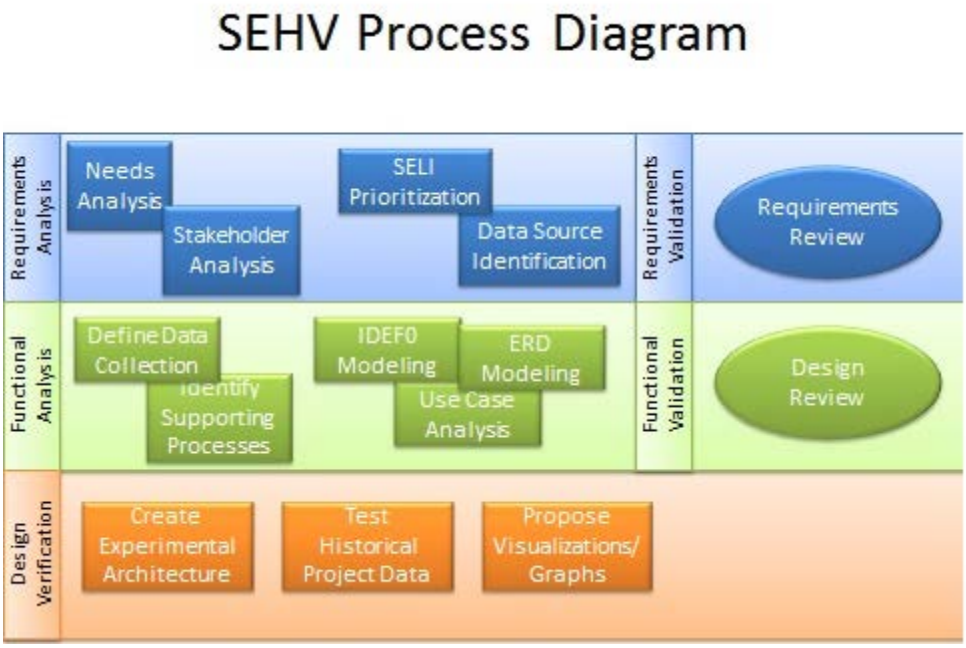


Figure 7 SEHV Process Diagram

3.1 PROBLEM DEFINITION/NEEDS ANALYSIS

The team will define the problem and perform needs analysis for the SEHV capability. This will include the stakeholder needs analysis, analysis of SSC-A current capabilities, and providing examples of programs that have failed or had issues as a result of a lack of insight into their SE health. Analysis of the SEHV capability needs will determine the overall boundaries, limitations, and constraints.

SSC-A is highly in need of a comprehensive understanding through dynamic displays of the overall health of its SE process areas against prescribed performance measures. SSC-A has the need to access specific SELIs to provide decision-makers dynamic and current visibility into quality and effectiveness of SE / SE management activities. The capability will assist SSC-A in the identification and diagnosis of potential SE / SE management problems either before they occur in order to mitigate them or after they occur in order to prevent like problems in the future. The entry criteria will include SSC-A stakeholders inputs, and the exit criteria would include documented stakeholder needs.

3.2 REQUIREMENTS ANALYSIS/METRICS ANALYSIS

The team will perform requirements analysis that will result in a functional requirements baseline for the solution. Requirement analysis will begin with ensuring that the SSC-A stakeholder's needs are adequately documented, understood, and suitable for refinement.

These will be reviewed against the project criteria, and agreed upon by the SSC-A active stakeholders, NPS advisors, and the SEHV Capstone Project team. The SEHV team will analyze SEHV leading indicators to facilitate project risk identification. The team will study the International Council on Systems Engineering's (INCOSE) Systems Engineering Leading Indicators (SELI) Guide version 2.0, which will be used as a reference for this project. The INCOSE SELI guide identifies 18 leading indicators that have been proven to provide insight into future project performance. The use of the SELIs will ensure levels of quality for the solution. SELIs will be reviewed and prioritized based on their impact to project cost and schedule, system performance, as well as, their ability to answer common questions posed by engineering managers concerning system risks. The entry criteria includes the project need statement and the exit criteria includes a stakeholder analysis, documented SEHV solution functional requirements, and a prioritized listing of SELIs based upon SSC-A stakeholder needs.

3.3 FUNCTIONAL ANALYSIS

The team will determine the data collection process required for each prioritized SELI, along with its respective data mapping, data translation, data storage, and data analysis methods. The details of the data elements, data sources, and anticipated positive or negative trending patterns will feed into the functions that comprise the SEHV system architecture. The data capture, data storage, and data management strategies for the data elements known to provide insight into targeted SELI trends - based upon INCOSE's SE Leading Indicator study - will be the outcome of this analysis. The SEHV team will develop an IDEF0 diagram as a part of the functional analysis. The entry criteria will include the data elements, data sources, and notional trending patterns of the most valued SELIs and the exit criteria will include an IDEF0 diagram depicting data capture methods and triggers, data transformation and storage functions, as well as, data management and archiving strategies.

3.4 SYSTEM ARCHITECTURAL MODELING

The project team will continue to refine the SEHV Context Diagram, as well as, the SSC Current State OV-1, and SEHV Capability OV-1 diagrams. The team will develop an architecture model to be used to facilitate development of the SEHV capability. Functional and physical architecture models will be created to assist in implementing the SEHV capability. The functional architecture model will be solution neutral while the physical architecture model will contain components that will be evaluated against specific criteria such as cost, availability, and feasibility. The team will also develop an Entity Relationship Diagram (ERD) to define the physical data model of the prospective

relational database structure. The entry criterion includes SEHV IDEF0 diagrams, positive, negative, and neutral SELI trending patterns, and data elements with associated source information. The exit criteria includes a functional architecture that allocates SEHV functions to specific components, as well as, an ERD that facilitates the storage and analysis of the SEHV dataset.

3.5 SYSTEM ANALYSIS

The team will perform an assessment of the SEHV capability against the functional requirements and operational use cases. Historical project data will be mapped to the proposed entity relationship model and the team will analyze the SEHV capability in identifying trends and insight into SE health. Notional graphs and dashboards will be created to present the information captured within the SEHV solution to the stakeholders. The team will perform a high level cost analysis of implementing the system and a risk analysis to identify any risks that SSC-A may encounter in implementing this SEHV capability. The entry criteria would include the functional architecture and physical architecture and the exit criteria will be a validated architecture against historical data and operational use cases along with potential visualization mechanisms.

4. PROJECT MILESTONES & DELIVERABLES

Deliverables will include a proposal, three IPR's and a final report. Table 5 lists the POA&M.

4.1 SCHEDULE

Table 5 SEHV Project POA&M

Task Name	Duration	Start	Finish
SSC LANT System Engineering Health & Visualization	190 days	Fri 3/21/14	Fri 12/12/14
NPS 1st Quarter	61 days	Fri 3/21/14	Fri 6/13/14
Strategy and Rollout	36 days	Fri 3/21/14	Fri 5/9/14
Draft Proposal	6 days	Fri 3/21/14	Fri 3/28/14
Metrics Gathering Strategy	14 days	Fri 3/21/14	Wed 4/9/14
Final Capstone Proposal (Due to the Advisor Inbox in Resources)	1 day	Fri 4/11/14	Fri 4/11/14
PMP Draft Submission	1 day	Fri 4/25/14	Fri 4/25/14
PMP Final Submission	1 day	Fri 5/9/14	Fri 5/9/14
Problem Definition / Needs Analysis	20 days	Fri 5/9/14	Thu 6/5/14
Document and express SSC-A Active stakeholder needs	16 days	Fri 5/9/14	Fri 5/30/14
Define the problem definition	20 days	Fri 5/9/14	Thu 6/5/14
Produce a requirements document	20 days	Fri 5/9/14	Thu 6/5/14
Requirements Analysis / Metrics Analysis	20 days	Fri 5/9/14	Thu 6/5/14
Identify Top Level "Driving Requirements"	10 days	Fri 5/9/14	Thu 5/22/14
Stakeholder Analysis	20 days	Fri 5/9/14	Thu 6/5/14
Analyze organizational SE & SE Mgmt. stakeholders and characterize their SELI needs	20 days	Fri 5/9/14	Thu 6/5/14
Data Source Identification	20 days	Fri 5/9/14	Thu 6/5/14

Analyze data elements produced by SELI	20 days	Fri 5/9/14	Thu 6/5/14
Chapter 1 of the Capstone Report	14 days	Tue 5/20/14	Fri 6/6/14
IPR Dry Run	11 days	Fri 5/23/14	Fri 6/6/14
IPR 1	5 days	Mon 6/9/14	Fri 6/13/14
End of 1st Quarter Stakeholder Approval (Control Gate)	0 days	Fri 6/13/14	Fri 6/13/14
NPS 2nd Quarter	65 days	Mon 6/16/14	Fri 9/12/14
Requirements Analysis / Metrics Analysis (Cont'd)	38 days	Mon 6/16/14	Wed 8/6/14
Most valued SELI based on the down select process	20 days	Mon 6/16/14	Fri 7/11/14
Down select SELI based on criteria such as SELI mapped to multiple stakeholders, automated method of capturing information, tools that produce data elements that are needed from SELI, existing / available SE / SE MGT tools, and cost	20 days	Mon 6/16/14	Fri 7/11/14
Document SEHV solution functional requirements	10 days	Thu 7/24/14	Wed 8/6/14
Document system concepts for the necessary automated data collection procedure	10 days	Thu 7/24/14	Wed 8/6/14
Functional Analysis	19 days	Wed 8/6/14	Mon 9/1/14
Develop a SEHV IDEF0	19 days	Wed 8/6/14	Mon 9/1/14
Identify and describe any additional information, mechanisms or integration needed to provide the SEHV solution	10 days	Wed 8/6/14	Tue 8/19/14
Identify system concepts to pull / push data onto the data model from sources	10 days	Wed 8/6/14	Tue 8/19/14
Identify system concepts for all data elements needed	10 days	Wed 8/6/14	Tue 8/19/14
Identify system concepts for data storage	10 days	Wed 8/6/14	Tue 8/19/14
Determine Display Mechanism Options to generate trend analysis	10 days	Tue 8/19/14	Mon 9/1/14
Assess available visualization tools or software components that can be used to generate graphical depictions of SELI in INCOSE SELI v2 specification	10 days	Tue 8/19/14	Mon 9/1/14

Chapter 2 & 3 of the Capstone Report	21 days	Fri 6/27/14	Fri 7/25/14
IPR 2 Draft	16 days	Fri 8/1/14	Fri 8/22/14
IPR 2 Rehearsal (advisors only)	10 days	Mon 8/25/14	Fri 9/5/14
Chapter 4 & 5 of the Capstone Report	35 days	Mon 7/28/14	Fri 9/12/14
IPR2 Presentation (All invited Stakeholders and Faculty)	18 days	Wed 8/20/14	Fri 9/12/14
End of 2nd Quarter Stakeholder Approval (Control Gate)	0 days	Fri 9/12/14	Fri 9/12/14
NPS 3rd Quarter	64 days	Mon 9/15/14	Fri 12/12/14
System Architectural Modeling	10 days	Mon 9/15/14	Fri 9/26/14
Operational use cases of SEHV capability	10 days	Mon 9/15/14	Fri 9/26/14
Assess available SE tools and other sources reporting and query mechanisms to identify how required data elements can be provided for SELI use	10 days	Mon 9/15/14	Fri 9/26/14
Develop a Entity Relationship Diagram for display mechanisms	10 days	Mon 9/15/14	Fri 9/26/14
Refine Diagrams (OV-1 & Concept)	10 days	Mon 9/15/14	Fri 9/26/14
System Analysis	20 days	Mon 9/15/14	Fri 10/10/14
Perform a high level cost analysis of implementing the system	20 days	Mon 9/15/14	Fri 10/10/14
Risk analysis to identify any risks that SSC-A may encounter in implementing the SEHV capability	20 days	Mon 9/15/14	Fri 10/10/14
Validate architecture against historical data and operational use cases along with potential visualization mechanisms	10 days	Mon 9/15/14	Fri 9/26/14
Draft Capstone Project Report	18 days	Fri 10/3/14	Tue 10/28/14
Draft Capstone Project Report (NPS Req.)	46 days	Fri 10/3/14	Fri 12/5/14
Use Thesis Processing Office's Template (NPS Req.)	21 days	Fri 10/3/14	Fri 10/31/14
Write Draft Chapters (NPS Req.)	21 days	Fri 10/3/14	Fri 10/31/14
Submit Draft Chapters to Thesis Processing (NPS Req.)	1 day	Fri 10/17/14	Fri 10/17/14

Submit Draft Chapters to Advisor (NPS Req.)	1 day	Fri 10/31/14	Fri 10/31/14
Capstone Project Report Submitted for Chair Signature (NPS Req.)	1 day	Wed 11/5/14	Wed 11/5/14
Revise Final Based on Advisor Feedback (NPS Req.)	3 days	Wed 11/19/14	Fri 11/21/14
Obtain Advisor's Approval of Final (NPS Req.)	3 days	Wed 11/26/14	Fri 11/28/14
Final Draft with Chair Revisions due to (TPO)	1 day	Fri 12/5/14	Fri 12/5/14
Final IPR 3 Rehearsal (advisors only)	1 day	Fri 12/5/14	Fri 12/5/14
Final IPR 3 (for stakeholders and faculty)	1 day	Fri 12/5/14	Fri 12/5/14
End of Final Quarter Stakeholder Approval (Control Gate)	0 days	Fri 12/12/14	Fri 12/12/14

4.2 PROJECT REVIEWS

The SEHV Capstone PM will monitor the project activities against the PMP to evaluate the actual performance and progress of the SEHV Capstone Project. In addition to the specific monitoring and control functions in section 2.3.1 above, the SEHV Capstone PM will coordinate, facilitate, and ensure stakeholder/team participation in quarterly IPR meetings. Through the IPRs and other controls described in this document, the SEHV Capstone PM will identify and document deviations from the PMP. The SEHV Capstone PM will collect and analyze the issues and determine the actions necessary to address the issues. Finally, the SEHV Capstone PM will take the requisite corrective action on any noncompliance issues and manage each to closure.

4.3 DELIVERABLES

The team will deliver both a SEHV Capstone final report and PMP. These artifacts serve as guides for the objectives and scope of the project. Three In-Progress Reviews (IPRs) will be conducted over the duration of this project. At each of the IPRs, the project team will review the project status and way ahead with the stakeholders. NPS faculty will also be present for the IPRs and ensure that quality SE is being performed for the project according to the NPS standards. The SEHV Capstone Project final report will capture the output of the planned activities from the capstone proposal and PMP. The final report is the major deliverable from this effort. Interim work products such as architectures and simulation results will be included in the report and will be available to stakeholders for follow on efforts.

Spring Quarter

28 Mar	Draft capstone proposal due to Advisor via Advisors' Inbox in Sakai SI0810 Resources. This is a team deliverable.
4 Apr	1st Meeting – meetings occur weekly after this date
11 Apr	Final capstone proposal due to the Advisors' Inbox in Resources
25 Apr	Draft Project Plan due
9 May	Final Project Plan due
6 Jun	Chapter 1 and the outline of the Capstone Report are due (to the Advisors' Inbox)
6 Jun	IPR 1 rehearsal (advisors only)
13 Jun	IPR 1 (all invited stakeholders and faculty)

Summer Quarter

25 Jul	Chapters 2 and 3 of the Capstone Report are due (to the Advisors' Inbox)
5 Sep	IPR 2 rehearsal (advisors only)
12 Sep	IPR 2 (all invited stakeholders and faculty)
12 Sept	Chapters 4 and 5 of the Capstone Report are due (to the Advisors' Inbox)

Fall Quarter

17 Oct	Initial draft of all sections of the Capstone Report is due (to the Advisors' Inbox)
1 Nov	Initial draft of the Capstone Report is due to the Thesis Processing Office (TPO) for format check (via SharePoint (SP))
5 Nov	Final draft of the Capstone Report (ready for advisor signature) is due to Heather Hahn (via SharePoint) for SE Department Chair Review
5 Dec	Final draft of the Capstone Report (incorporating any revisions from the Dept. Chair) is due to the TPO (facilitated by Heather Hahn)
5 Dec	Final IPR 3 rehearsal (for advisors)
12 Dec	Final IPR 3 (for stakeholders and faculty)

APPENDIX A ACRONYMS AND ABBREVIATIONS

The following acronyms are used in this plan:

Acronym	Definition
AHP	Analytic Hierarchy Process
ALI	Applied Leading Indicators
CCB	Configuration Control Board
CIMS	Career Information Management System
CM	Configuration Management
CMGR	Configuration Manager
COG	Command Operating Guide
CRM	Customer Relationship Model
DCO	Defense Connect Online
DC/ESE	Data Center / Enterprise Services Environment
DIMHRS	Defense Information Management Human Resource System
DOD	Department of Defense
DODAF	Department of Defense Architecture Framework
ERD	Entity-Relationship Diagram
FFBD	Functional Flow Block Diagram
IEEE	Institute of Electrical and Electronics Engineers
INCOSE	International Council on Systems Engineering
IPR	In-Progress Review
ISO	International Organization for Standardization
JF	Joint Framework
LSE	Lead System Engineer
MGMT	Management
MS	Microsoft
MSES	Master of Science in Engineering Systems
MSSE	Master of Science in Systems Engineering

MVI	Master Veteran Index
NAVAIR	Naval Air
NPS	Naval Postgraduate School
NSIPS	Navy Standard Integrated Performance System
OV	Operational View
PM	Project Manager
PMP	Project Management Plan
POA&M	Plan of Actions and Milestones
PSE	Program Support Engineer
PSM	Practical Software and Systems Measurement
QA	Quality Assurance
QM	Quality Management
REQM	Requirements Management
ROM	Rough Order of Magnitude
SE	Systems Engineering
SEHV	System Engineering Health and Visualization
SELI	System Engineering Leading Indicator
SEMP	System Engineering Management Plan
SME	Subject Matter Expert
SP	Share Point
SPAWAR	Space and Naval Warfare
SSC-A	Space and Naval Warfare Systems Center Atlantic
TFFMPS	Total Force and Fleet Manpower System
TPO	Thesis Processing Office
VA	Veteran Affairs
V&V	Verification and Validation
WBS	Work Breakdown Structure
XML	Extendible Markup Language

APPENDIX B SEHV CAPSTONE PROJECT TOOLS AND PLANS

Table 6 provides a listing of the tools and plans that will be used to support the SEHV Capstone Project Management, Architecture and Simulation Modeling processes.

Table 6 SEHV Capstone Project Management Tools and Plans

Function	Tool(s) Used
Requirements Management	Innoslate
Schedule Management	MS Project
Communications Management	Email, MS Excel
Risk Management	Risk Matrix, List
Configuration Management	Google Docs
Document Repository	Google Docs, Sakai Site, MS Outlook
Architecture / Simulation Modeling	Innoslate, MS Visio

APPENDIX C GLOSSARY

- Configuration Control Board (CCB)

The CCB is a group that assists with an organization's overall network strategy. The CCB is a group of project stakeholders responsible for evaluating and approving or disapproving proposed changes to a system or strategy. The CCB is also responsible for prioritizing and scheduling approved change for upcoming releases of the system.

- Entity-Relationship Diagram (ERD)

An ERD is a data modeling technique that creates a graphical representation of the entities, attributes, and relationships within an information system.

- Institute of Electrical and Electronics Engineers (IEEE)

A large technical professional society promoting the development and application of electro-technology and allied sciences for the benefit of humanity, the advancement of the profession, and the well-being of our members. The IEEE fosters the development of standards that often become national and international standards. The organization publishes a number of journals, has many local chapters, and several large societies in special areas.

- International Council on Systems Engineering (INCOSE)

INCOSE is a not-for-profit membership organization founded in 1990. Their mission is to share, promote and advance the best of systems engineering from across the globe for the benefit of humanity and the planet.

- International Organization for Standardization (ISO)

The ISO is the largest developer of voluntary international standards.

- Work Breakdown Structure (WBS)

The WBS is a decomposition of all the work necessary to complete a project.

APPENDIX D LIST OF FIGURES AND TABLES

Figure 1 SSC-A Current State w/o SEHV OV-1 146
Figure 2 SEHV Capability Context Diagram 148
Figure 3 SEHV Capability OV-1 149
Figure 4 SEHV Capstone Project Organizational Structure.....151
Figure 5 SEHV Project Approach 158
Figure 6 SEHV Systems Engineering Process.....159
Figure 7 SEHV Process Diagram.....160

Table 1 SEHV Capstone Project Team Roles and Responsibilities.....152
Table 2 Stakeholder Roles and Responsibilities 153
Table 3 Communications Management 155
Table 4 SELI Trends 157
Table 5 SEHV Project POA&M.....163
Table 6 SEHV Capstone Project Management Tools and Plans.....170

REFERENCES

Institute of Electrical and Electronics Engineers (IEEE). 2007. *IEEE Standard 1220–2005. "Systems engineering — Application and management of the systems engineering process."* ISO/IEC 26702. First Edition.

International Council on Systems Engineering (INCOSE), Lean Aerospace Initiative, Systems Engineering Advancement Research Initiative, and PSM. 2007. "*Systems Engineering Leading Indicators Guide.,"* edited by Garry Roedler and Donna H. Rhodes. Version 1.0. http://seari.mit.edu/documents/LAI-Leading-Indicators-Update-20070618.pdf.

International Council on Systems Engineering (INCOSE), Lean Aerospace Initiative, Systems Engineering Advancement Research Initiative, and PSM. 2010. "*Systems Engineering Leading Indicators Guide.,"* edited by Garry Roedler, Donna H. Rhodes, Howard Schimmoller, and Cheryl Jones. Version 2.0. http://seari.mit.edu/documents/SELI-Guide-Rev2.pdf.

Montgomery, Paul, and Ron Carlson. 2010. *"Systems Engineering Applied Leading Indicators' Enabling Assessment of Acquisition Technical Performance."* last accessed: May 2014. https://calhoun.nps.edu/public/bitstream/handle/10945/33585/NPS-AM-10-175.pdf?sequence=1

Rhodes, Donna H., Ricardo Valerdi, and Garry J. Roedler. 2008. *"Systems Engineering Leading Indicators for Assessing Program and Technical Effectiveness."* Preprint of article accepted for publication in Systems Engineering. (Wiley Periodicals, Inc. 2008). http://www.pdfdom.com/pdflib/20140421/systems-engineering-leading-indicators-for-seari-at-mit.pdf

Ugone, Mary L. 2010. *"Results in Brief: Acquisition Decision Memorandum for the Defense Integrated Military Human Resources System."* last accessed: June 2014. http://www.dodig.mil/audit/reports/fy10/10-041redacted.pdf

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX C. SSC-A'S CAO CONOPS AND IPT HANDBOOK STAKEHOLDER CHARACTERIZATION WRT SELIS

Command Senior Leadership Staff

Weekly Staff Meeting metrics monitor Command-wide activities that may impact IPT performance and vary based on Command priorities. Metrics include cycle times for key processes that require leadership attention to drive end-to-end efficiencies (CONOPS Pg. 38 SELI 12)

The Commanding Officer (CO) and Executive Director (ED), along with the governance entities shown in Figure 3, SSC-A Senior Leadership and Governance Structure, ensures the efficient flow of processes across the local competencies and the sharing of best processes with SPAWAR Systems Command (SPAWARSYSCOM) (CONOPS Pg. 4 SELI 12)

CODE 01B DIRECTOR OF MANAGEMENT OPERATIONS

The ED serves on the SPAWAR Business Board, institutes processes required to achieve programs and mission goals, and provides conflict resolution and balance between competency priorities and business unit priorities. (CONOPS Pg. 4 SELI 12)

The CO and ED, along with the governance entities shown in Figure 3, SSC-A Senior Leadership and Governance Structure, ensures the efficient flow of processes across the local competencies and the sharing of best processes with SPAWARSYSCOM (CONOPS Pg. 4 SELI 12)

The director's goal is to manage business operations around cross-functional end-to-end business processes that produce financial and other performance information with greater accuracy, reliability, and accessibility (CONOPS Pg. 4 SELI 12)

The ED focuses on ensuring cost-effective operations, maintains a supportive work environment capable of accomplishing all assigned roles and responsibilities, and oversees the technical performance of work performed within SSC-A. (CONOPS Pg. 4 SELI 9, 13, 16, 18)

CODE 01E DIRECTOR OF INTEGRATION AND EFFICIENCY

The Director of Integration and Efficiency focuses on developing and deploying effective processes that operate across the command to achieve organizational efficiency. (CONOPS Pg. A-3 SELI 12)

CODE 01I INSPECTOR GENERAL

Through the assessment of internal controls and related risks, the Office of Inspector General (OIG) prevents and detects fraud, waste, abuse, and mismanagement within the organization. (CONOPS A-3 SELI 9, 10)

It provides services to management by objectively assessing activities, reporting on findings, providing independent advice and technical guidance, and recommending policies and processes changes to prevent and detect fraud, waste, abuse, and mismanagement. (CONOPS A-4 SELI 12)

Business Portfolio

The Business Portfolio Board (BPB) is the first of two major governance boards chartered by the ESC to focus on long-term visionary and strategic planning, processes, and resources for business execution. (CONOPS Pg. 5 SELI 12, 14)

A Sub Portfolio's (SP) responsibilities are to coordinate efforts across a collection of IPTs and other subportfolios to ensure maximum cost, schedule, and performance efficiencies. (IPT Handbook Pg. 2 SELI 9, 13, 16, 18)

Coordinate projections of the resources that will be needed to meet anticipated requirements across fiscal years are collected in IPT Workbooks by the portfolios. The workbook provides personnel (series/level/geographic preference, KSA, special certifications), laboratories facilities, and contract requirements. (CONOPS Pg. 21 SELI 14)

The portfolio structure enables the command to manage and have sound accountability of cost, schedule, and performance; ensure effective and timely delivery of products and services; and speak with a single command-voice in each business area. (CONOPS Pg. 6 SELI 9, 16, 18)

Working with the Support Agreements Manager (SAM), functional managers review customer requests to determine SSC-A's capability to provide the requested support, develop draft support agreements, determine the impact of the mission, and identify costs and resources to provide the support. (CONOPS Pg. 18 SELI 9, 16)

At SSC-A, BPs are responsible for the overall execution of the tasking and funding (cost, schedule, and performance) in support of the customer, and for management and organization of the customer relationship.(IPT Handbook Pg. 1 SELI 9, 16, 18)

BPs will coordinate across SSC-A and the SPAWAR Enterprise, as necessary, to ensure that the customer is provided the right work and right team, in the right place, and at the right cost and capability. (IPT Handbook Pg. 3 SELI 9, 16)

BUSINESS PORTFOLIO MANAGER (BPM)

The objectives of BP management are to optimize the mix of resources used to produce and deliver the end item and to schedule activities that achieve SSC-A's goals within constraints imposed by customers, strategic objectives, and external factors. (CONOPS Pg. 8 SELI 11, 14, 18)

BPMs and SPLs monitor the environment, analyze key factors, forecast resource needs, and develop business plans in order to prepare for and sustain future work. (CONOPS Pg. 8 SELI 11, 14)

The BPMs shape the portfolio content and oversee the cost, schedule, and performance outcomes of their assigned portfolio. (CONOPS Pg. B-2 SELI 9, 16, 18)

BPMs ensure that cost-effective solutions are provided to customers with similar requirements. (IPT Handbook Pg. 2 SELI 9, 16)

DEPUTY PORTFOLIO MANAGER (DPM)

DPMs are responsible for daily BP operations, cost, schedule, and performance oversight; support the BP strategic efforts; and lead and advise the BP senior staff regarding the actions of the boards. (CONOPS Pg. B-2 SELI 9, 16, 18)

PORTFOLIO SYSTEMS ENGINEER (PSE)

Each PSE supports his/her aligned BPM during customer engagements to understand and then communicate the scope of the initial engineering requirements to the SPL and IPT Lead. (CONOPS Pg. B-2 SELI 1, 4, 5)

All products offered by their aligned BP adhere to Federal standards for interoperability, comply with Federal mandated architectures, and use system-of-systems engineering practices to advance the enterprise IT capability of the Warfighter. (CONOPS Pg. B-2 SELI 12, 17)

SUBPORTFOLIO LEAD (SPL)

Sub-IPT Leads may come from any competency but must possess the requisite KSAs and A&Es to effectively manage the cost, schedule, performance, and risks of their assigned project or tasks. (IPT Handbook Pg. B-5 SELI 9, 10, 16, 18)

SPLs will assist with negotiated resource allocations (workforce Demand Signals, facilities, lab space, contracts, etc.) with the competencies. (IPT Handbook Pg. D-1 SELI 11, 14)

The SPL is accountable for the cost, schedule, performance, and risk of the SP. (IPT Handbook Pg. 5 SELI 9, 13, 16)

BPMs and SPLs monitor the environment, analyze key factors, forecast resource needs, and develop business plans in order to prepare for and sustain future work. (CONOPS Pg. 8 SELI 11, 14)

BPMs and SPLs assess and forecast resource requirements for the competencies and BPs. (IPT Handbook Pg. 6 SELI 11, 14)

The Handshake is command-required documentation that defines the scope, schedule, cost, and performance of a project and is signed by both the designated Portfolio/SPL approver and the project sponsor or customer. (IPT Handbook Pg. 18 SELI 9, 15, 16, 18)

An SPL is responsible for one or more projects within a portfolio and for one or more IPTs. They are responsible for project cost, schedule, and performance oversight of the IPTs within the sub-portfolio. (CONOPS Pg. B-3 SELI 16)

INTEGRATED PRODUCT TEAM (IPT) LEAD

The IPT Lead works with IPT members to iteratively refine customer requirements, cost estimates, resource projections, and update Project Planning Monitoring and Control (P2MC) and Navy ERP. The IPT Lead collaborates with

support competencies during the Planning and Customer Requirements Phase. (CONOPS Pg. 31 SELI 16)

The Leads engage the appropriate subject matter experts (SME) to initiate the execution of the necessary process or processes as needed throughout the Project Life Cycle (PLC). (CONOPS Pg. 30 SELI 12)

Risk Management (CONOPS Pg. 30 SELI 9, 10)

The IPT Lead should have experience with the technology involved in the project, adequate familiarity in the AOR, and appreciation of IPT members' capabilities. Detailed IPT Lead roles and responsibilities are defined in the IPT Handbook. (CONOPS Pg. B-3 SELI 8)

The IPT Lead engages in early project management high level planning activities, and reviewing the description of the work contained in the Mission Alignment record. High level planning in project initiation typically includes high level refinement and management of requirements, risks, cost, and communications, and the development of a Work Breakdown Structure (WBS), Organizational Breakdown Structure (OBS), schedule, demand signals, charter, and Team Assignment Agreements (TAAs) (IPT Handbook Pg. 12 SELI 9, 10, 18)

The IPT Lead tracks and monitors all project activities and controls deviations from the base-lined PMP. This is achieved by monitoring and controlling project execution, cost, schedule, scope, and risks for each activity in the project. (IPT Handbook Pg. 21 SELI 9, 10, 18)

IPT Leads may come from any competency but must possess the requisite KSAs and A&Es to effectively manage the cost, schedule, performance, and risks of their assigned project or tasks. An IPT Lead must also follow the 6.0 Program and Project Management CDM. (IPT Handbook Pg. 12 SELI 9, 10, 18)

The IPT Lead and Competency Managers will identify qualified team members (also known as a "Competency Member of an IPT" or CMoI) through negotiated interaction and discussion of the required tasks (Refer to Section 3.1 for early communications of personnel resource requirements) (IPT Handbook Pg.17 SELI 11)

The IPT Lead is responsible for assisting and negotiating with competency representatives for personnel resource requirements or Demand Signal for the IPT (IPT Handbook Pg.17 SELI 11)

The IPT Lead will also provide feedback to Competency Managers for employee accomplishments for performance evaluations and for any schedule or resource deviations which have the potential to affect the competency. (IPT Handbook Pg. 22 SELI 11, 18)

The IPT Lead manages complex change by providing vision, skills, demand signal, resources, and action plans to effectively respond to changing requirements. (IPT Handbook Pg. C-2 SELI 11)

The IPT Lead has the authority to size the IPT in support of the requirements.

The IPT Lead is responsible for coordinating with the portfolios, SPs, and competencies to resolve issues due to scope, funding, performance, and resource priorities. (IPT Handbook Pg. D-2 SELI 11)

The IPT Lead assesses, forecast, and maintain resource demand signals for a 2-year outlook (execution +1 year). (IPT Handbook Pg. 7 SELI 11)

The IPT Lead communicates resource status and ensure efficient resource utilization (IPT Handbook Pg. 7 SELI 11)

The IPT Lead engages all competencies necessary to develop a project resources plan; this plan defines resource requirements including personnel, facilities (administrative, warehouse, laboratory), IT, and materials. (IPT Handbook Pg. 13 SELI 11)

Each IPT Lead collaborates early and often with Competency Managers to negotiate IPT membership and obtain personnel with the required Knowledge, Skills, and Abilities/Assignment & Experience (KSAs/A&E) from organizationally-aligned competency resources. (IPT Handbook Pg.16 SELI 11)

The IPT Lead is responsible for assisting and negotiating with competency representatives for personnel resource requirements or Demand Signal for the IPT. (IPT Handbook Pg. 16 SELI 11)

IPT members or CMoI shall perform their work in accordance with cost, schedule, performance, and risk parameters set by the IPT Lead utilizing common work processes and the operational policies, procedures, and standards of the competency. (IPT Handbook Pg. 22 SELI 9, 12, 18)

The IPT Lead engage all members in the IPT process by soliciting inputs and applying active listening skills (IPT Handbook Pg. 24 SELI 12)

The IPT Lead identify, document, mature, and use standardized processes across projects to enable quality, speed, agility, and value (IPT Handbook Pg. C-3 SELI 12)

The IPT Lead develops a detailed Project Management Plan (PMP) to define how the project is to be executed, monitored and controlled, and closed. PMP planning documentation includes the agreed-to customer requirements; project scope, schedule, and resource requirements; project WBS organizational breakdown structure (OBS); plans for project data and reporting; plans for communications; other documents necessary to monitor the project cost, schedule, and performance; control variances from the project plan; produce and deliver the end product; and closeout the project. (CONOPS Pg. 29 SELI 9, 13, 16, 18)

IPT Leads and Competency Leads confer frequently to evaluate performance of competency members and address performance issues to ensure that CMoI performance is in accordance with the TAAs, meets the IPT requirements, respective competency policies and processes, and that competency member development needs are being addressed.(CONOPS Pg. 30 SELI 13)

Manage day-to-day cost, schedule, performance, and risk elements of the IPT. (IPT Handbook Pg.7 SELI 9, 13, 16, 18)

Collect and measure performance data (Health Metrics) and report results to the SPL and BPM overseeing the project (IPT Handbook Pg. 7 SELI 13)

Focus on needs of customer: Identifying Customer Needs - Measuring Performance - Establishing Project Controls (IPT Handbook Pg. C-1 SELI 13)

The IPT Lead gathers and measure performance data (IPT Handbook Pg. C-2 SELI 13)

The IPT Lead report performance measures to portfolio and competency leadership. (IPT Handbook Pg. C-2 SELI 13)

Measure performance, track performance measurements, and use CMMI processes (IPT Handbook Pg. C-4 SELI 13)

IPT Lead selection occurs early in the project. This allows the IPT Lead to participate in key startup decisions such as project resource planning. The IPT Lead is the hands-on, day-to-day manager of the project and the person most directly responsible for the success of the project. (CONOPS Pg. 26 SELI 14)

The IPT Lead engages the competencies with the preponderance of the work to develop a project resources plan; this plan defines resource requirements including personnel, facilities, warehousing and laboratory space. (CONOPS Pg. 26 SELI 14)

IPT Lead sends the ROM cost to the customer and discusses the resourcing approach to ensure funds are provided as needed to support the project. (CONOPS Pg. 27 SELI 14)

The IPT Lead develops a detailed Project Management Plan (PMP) to define how the project is to be executed, monitored and controlled, and closed. PMP planning documentation includes the agreed-to customer requirements; project scope, schedule, and resource requirements; project WBS organizational breakdown structure (OBS); plans for project data and reporting; plans for communications; other documents necessary to monitor the project cost, schedule, and performance; control variances from the project plan; produce and deliver the end product; and closeout the project. (CONOPS Pg. 29 SELI 14)

Communicate resource status and ensure efficient resource utilization (IPT Handbook Pg. 7 SELI 14)

The IPT Lead engages all competencies necessary to develop a project resources plan; this plan defines resource requirements including personnel, facilities (administrative, warehouse, laboratory), IT, and materials. (IPT Handbook Pg. 13 SELI 11, 14)

IPT Leads will gather requirements and provide to the Competency Lead in support of facilities requests. The Competency Lead will submit request(s) for facilities (lab, warehouse, and administrative) resources in support of the IPT.

(SPAWARSYSCENLANT 5900/2 (Rev. 06/12)) (IPT Handbook Pg. D-2 SELI 14)

The IPT Lead conducts lessons learned workshops/activities and post project reviews to ensure data collected is added to documents such as the PMP for complete and accurate documentation. (CONOPS Pg. 37 SELI 15)

The PMP will be developed by the IPT Lead with input from the customer and other key stakeholders. (CONOPS Pg. 19 SELI 15)

The IPT Lead tracks and monitors all project activities and controls deviations from the baseline PMP. This is achieved by monitoring and controlling project execution, cost, schedule, scope, and risks for each activity in the project. (CONOPS Pg. 29 SELI 9, 16, 18)

The IPT Lead conducts lessons learned workshops/activities and post project reviews to ensure data collected is added to documents such as the PMP for complete and accurate documentation. This will allow for full accounting of information and can expedite and cut costs of future projects. (CONOPS Pg. 37 SELI 9, 16)

The IPT Lead engages in early project management high level planning activities, and reviewing the description of the work contained in the Mission Alignment record. High level planning in project initiation typically includes high level refinement and management of requirements, risks, cost, and communications, and the development of a Work Breakdown Structure (WBS), Organizational Breakdown Structure (OBS), schedule, demand signals, charter, and Team Assignment Agreements (TAAs). (IPT Handbook Pg. 12 SELI 9, 16, 18)

Each IPT shall have a designated leader who is accountable for the cost, schedule, performance, and risk of the IPT (IPT Handbook Pg. 6 SELI 9, 16, 18)

A preliminary schedule and ROM cost estimate (can be used to for Handshake Artifact estimates) are established; schedules and cost estimates become more accurate as more information becomes available. (IPT Handbook Pg. 13 SELI 9, 16, 18)

The IPT Lead tracks and monitors all project activities and controls deviations from the base-lined PMP. This is achieved by monitoring and controlling project

execution, cost, schedule, scope, and risks for each activity in the project. (IPT Handbook Pg. 21 SELI 9, 16, 18)

The IPT Lead will report up his or her IPT chain of command business accomplishments based on cost, schedule, performance, and risk, and will be held accountable for those elements (IPT Handbook Pg. 22 SELI 9, 16, 18)

IPT Leads may come from any competency but must possess the requisite KSAs and A&Es to effectively manage the cost, schedule, performance, and risks of their assigned project or tasks. (IPT Handbook Pg. B-3 SELI 9, 16, 18)

IPT TECHNICAL LEAD

This role ensures that proper technical activities are being conducted including determining and recommending the correct technical competency staffing and resources necessary for work execution to IPT Lead, overseeing technical work execution, reviewing deliverables for technical content and correctness, providing signatures on technical documentation where necessary, and ensuring proper technical reviews are being conducted in accordance with command directives. (CONOPS Pg. B-4 SELI 6)

The IPT Technical Lead provides technical guidance as necessary in accordance with command initiatives and directives, advises the IPT on technical risks, and issues and makes recommendations as a direct support to the IPT Lead. (CONOPS Pg. B-4 SELI 10)

The Leads engage the appropriate subject matter experts (SME) to initiate the execution of the necessary process or processes as needed throughout the PLC. (CONOPS Pg. 30 SELI 12)

Project-specific process development and management is the responsibility of the IPT Lead. (CONOPS Pg. D-3 SELI 12)

This role ensures that proper technical activities are being conducted including determining and recommending the correct technical competency staffing and resources necessary for work execution to IPT Lead, overseeing technical work execution, reviewing deliverables for technical content and correctness, providing signatures on technical documentation where necessary, and ensuring proper technical reviews are being conducted in accordance with command directives. (CONOPS Pg. B-4 SELI 14, 15)

5.0 Competency

Competencies provide personnel resources for project execution. However, competencies often find it necessary to contract with industry partners who provide contractor employees to augment competency resources. A Government-to-industry ratio is not prescribed on projects; however how effectively each project uses competency resources is monitored. Sourcing and personnel decisions must be carefully examined to ensure there is adequate and qualified in-house Government expertise involved in and providing oversight on every project. (CONOPS Pg. G-3 SELI 11)

Command's competencies are responsible for providing personnel resources, either government or industry, required by an IPT to execute the BP's work efforts. (IPT Handbook Pg. 2 SELI 11)

Communicate resource requirements (Demand Signal). (IPT Handbook Pg. 6 SELI 11)

The IPT Lead engages all competencies necessary to develop a project resources plan; this plan defines resource requirements including personnel, facilities (administrative, warehouse, laboratory), IT, and materials. (IPT Handbook Pg. 13 SELI 11)

It should be noted that SSC-A competencies provide standardized command processes, templates, tools, and other process assets for IPTs' use. (IPT Handbook Pg. 20 SELI 12)

Technical authorities provide technical expertise in the warranted competency area as well as establish standards, requirements, and processes to ensure consistency and product conformity. (CONOPS Pg. 10 SELI 12)

The LCL advises the NCL of competency demand, workforce development needs, work processes, and operating standards appropriate to the elements of the competency to which they are assigned (CONOPS Pg. D-2 SELI 12)

The Competency Board (CB) is the second of the two major governance boards chartered by the ESC to focus on long-term visionary and strategic planning, processes, and resources for competency execution. This board governs the competencies and provides strategic and tactical direction, guidance, oversight,

and conflict resolution to ensure consistent handling of all resources across the Command. (CONOPS Pg. 5 SELI 14)

Competencies provide the resources—people, processes, facilities, contracts, and tools—needed by the IPTs to deliver products and services to customers. (CONOPS Pg. 8 SELI 14)

The IPT Lead engages the competencies with the preponderance of the work to develop a project resources plan; this plan defines resource requirements including personnel, facilities, warehousing and laboratory space. (CONOPS Pg. 26 SELI 14, 16)

At SSC-A, the competencies are the organizational elements that provide resources (people, processes, and tools) to carry-out the Command's work. (IPT Handbook Pg. 1 SELI 14)

Under the IPT process, the Engineering Competency provides systems engineering and core engineering skills to other SSC-A competencies. Core skills are provided in support of warfighting technologies and systems; system designs; systems engineering within and across platforms, domains, and missions; test, evaluation, and certification of systems and capabilities; analyzing system data; determining and implementing corrective actions; ensuring security, safety, affordability, reliability, maintainability, usability, and availability of systems; and performing engineering assessments, cost estimations, and investigations. (CONOPS Pg. E-4 SELI 16)

Obtain cost estimates from appropriate competencies (IPT Handbook Pg. 8 SELI 16)

TIER 1 LOCAL COMPETENCY LEAD (LCL)

The Tier 1 Local Competency Leads (LCL) establishes Tier 2 Competency Lead (CL), Tier 3 Competency Manager (CM), and Tier 4 Competency Supervisor (CS) positions to support competency execution requirements.

LCLs consult with the SPAWAR National Competency Leads (NCL), who have overall authority and responsibility for all SPAWAR competencies, to ensure consistent competency KSAs, processes, and tools are developed in accordance with NCL guidance and are available as needed across SSC-A (CONOPS Pg. D-2 SELI 12)

LEAD SYSTEMS ENGINEER (LSE)

Performing engineering reviews to ensure proper interpretation and implementation of engineering processes and procedures used to produce end item products. (CONOPS Pg. D-3 SELI 7, 12)

The LSE ensures, through disciplined systems engineering, that all products and services adhere to competency standards, comply with federally mandated architectures, and advance the enterprise information technology capability of the Warfighter. (CONOPS Pg. D-2 SELI 17)

CONTINUOUS PROCESS IMPROVEMENT (CPI) LEAD

The CPI Lead collaborates within and across the SSC-A leadership team regarding improvement requirements, planning, and execution. The CPI lead coordinates and manages Lean Six Sigma black and green belt assignments as well as training requirements to implement improvements.

The CPI Executive Steering Group (ESG) represents the interests of portfolios, competencies, and command-level process leads to ensure that a structured method is used to consider proposed changes to command processes. (CONOPS Pg. 21 SELI 12)

PROCESS OWNER

The Process Owner can be assigned at any level of a competency. The Process Owner is responsible for overseeing and managing compliance with the competency's processes, procedures, data models, policies, metrics, and technologies. (CONOPS Pg. D-3 SELI 12)

The Process Owner ensures the process is used as required and the control plan is implemented and monitored. (CONOPS Pg. D-3 SELI 12)

PROCESS MANAGER

The Process Manager plans and coordinates activities required to perform, monitor and report on the process. (CONOPS Pg. D-3 SELI 12)

The Process Manager collects process measurement data to ensure the expected output is achieved. (CONOPS Pg. D-3 SELI 13)

COMPETENCY ADMINISTRATIVE SUPPORT

Support Services Specialist (SSS) functions are similar to the AO functions with specific focus on the assigned competency's requirements. (CONOPS Pg. D-4 SELI 1,4,5)

TIER 2 COMPETENCY LEAD (CL)

The Tier 1 Local Competency Leads (LCL) establish Tier 2 Competency Lead (CL), Tier 3 Competency Manager (CM), and Tier 4 Competency Supervisor (CS) positions to support competency execution requirements. (CONOPS Pg. D-4 SELI 11)

The Competency Lead will submit request(s) for facilities (lab, warehouse, and administrative) resources in support of the IPT. (SPAWARSYSCENLANT 5900/ 2 (Rev. 06/12)) (IPT Handbook Pg. D-2 SELI 11)

IPT Leads and Competency Leads confer frequently to evaluate performance of competency members and address performance issues to ensure that CMoI performance is in accordance with the TAAs, meets the IPT requirements, respective competency policies and processes, and that competency member development needs are being addressed. (CONOPS Pg. 30 SELI 13)

The CL is responsible for all of the competency's resources: personnel including their development and assignment, processes, and tools. (CONOPS Pg. D-4 SELI 14)

TIER 3 COMPETENCY MANAGER (CM)

The Tier 1 Local Competency Leads (LCL) establishes Tier 2 Competency Lead (CL), Tier 3 Competency Manager (CM), and Tier 4 Competency Supervisor (CS) positions to support competency execution requirements. (CONOPS Pg. D-4 SELI 11)

The IPT Lead and Competency Managers will identify qualified team members (also known as a "Competency Member of an IPT" or CMoI) through negotiated interaction and discussion of the required tasks (Refer to Section 3.1 for early communications of personnel resource requirements). (IPT Handbook Pg. 17 SELI 11)

If current competency resources are not available to support the project, the Competency Manager will evaluate the need to develop or hire the required resources via the Demand Signal Process. (IPT Handbook Pg. 17 SELI 11)

The IPT Lead will also provide feedback to Competency Managers for employee accomplishments for performance evaluations and for any schedule or resource deviations which have the potential to affect the competency. (IPT Handbook Pg. 22 SELI 11, 18)

Each IPT Lead collaborates early and often with Competency Managers to negotiate IPT membership and obtain personnel with the required Knowledge, Skills, and Abilities/Assignment & Experience (KSAs/A&E) from organizationally-aligned competency resources. (IPT Handbook Pg.16 SELI 11)

TIER 4 COMPETENCY SUPERVISOR (CS)

The Tier 1 Local Competency Leads (LCL) establishes Tier 2 Competency Lead (CL), Tier 3 Competency Manager (CM), and Tier 4 Competency Supervisor (CS) positions to support competency execution requirements. (CONOPS Pg. D-4 SELI 11)

The Team Assignment Agreement (TAA) establishes interrelationships and responsibilities between the competency performing individual, the IPT Leadership, and the individual's Competency Supervisor. (IPT Handbook Pg. 16 SELI 11)

FIRST-LINE SUPERVISOR

The Team Assignment Agreement (TAA) establishes interrelationships and responsibilities between the competency performing individual, the IPT Leadership, and the individual's Competency Supervisor. (IPT Handbook Pg. 16 SELI 11)

First-Line Supervisor provides additional Performance Management information. (CONOPS Pg. 31 SELI 13)

CONTRACTING OFFICER`S REPRESENTATIVE (COR)

The COR works in conjunction with the IPT lead to ensure the IPT is resourced efficiently to execute the COR function. (IPT Handbook Pg. 14 SELI 11, 14)

The COR Resource Guide (CRG) has been established to assist the COR and the IPT lead with assigning roles to CMoI personnel in an effort to effectively and efficiently execute the COR functional role. (IPT Handbook Pg. 14 SELI 11)

To assist in monitoring contractor performance, the IPT requests, competency nominates, and the Contracts Competency appoints CORs for all services task orders. (CONOPS Pg. D-5 SELI 13)

Additionally, the COR develops a Contract Performance Assessment Reporting System (CPARS) Draft Approval Document (CDAD) for all task orders and an actual CPARS evaluation for all orders over $1M. (CONOPS Pg. D-6 SELI 13)

Particular project cost estimate should be tailored to meet the requirements of the level of complexity of the technical order (TO). (IPT Handbook Pg. 14 SELI 16)

Integrated Product Team

They perform under the direction of an IPT Lead to produce products and services for customers based on requirements contained in a statement of work or similar document. The purpose of the IPT Execution is to deliver end products that meet customer requirements on schedule and within the budget. Engineering members of the IPT use engineering design processes to decompose high-level requirements into functional requirements. The S&T and Engineering members of the IPT collaborate to develop portfolio awareness of new technologies and to match these technologies with IPT requirements. Logistics and Fleet Support members of the IPT provide project configuration management to ensure the end-product complies with the design developed in the System Requirements Design Phase. (CONOPS Pg. 11 SELI 1, 4, 5, 18)

The Science and Technology (S&T) and Engineering members of the IPT collaborate to develop portfolio awareness of new technologies and to match these technologies with IPT requirements. (CONOPS Pg. 32 SELI 8)

The S&T Competency supports the IPT with the transition of new technology concepts and components to the engineering community for incorporation into the end-product. (CONOPS Pg. 33 SELI 8)

The sponsor’s process or product addresses or makes provisions for meeting SSC-A’s key process requirements, the IPT may be authorized to substitute the

sponsor's process/product in lieu of the command's standardized process/asset. (IPT Handbook Pg. 20 SELI 12)

IPT members or CMoI shall perform their work in accordance with cost, schedule, performance, and risk parameters set by the IPT Lead utilizing common work processes and the operational policies, procedures, and standards of the competency. (IPT Handbook Pg. 22 SELI 12, 18)

IPTs observe, measure, and report project performance in the P2MC and Navy ERP systems. Project monitoring above the SSC-A level is supported by Enterprise Cost Management Framework (ECMF) tagging. ECMF provides a common language about resources requirements, work, products, and services across the Navy. Tagging Navy ERP records enables visibility into financial resources at all levels of the Navy. (CONOPS Pg. 29 SELI 13)

Engineering members of the IPT use engineering design processes to decompose high-level requirements into functional requirements, identify system design specifications, and prepare design level artifacts that represent the end-product to be delivered to the customer. Engineering activities include developing a logical solution and documenting the solution design; developing, applying, and documenting the physical design and platform requirements; designing and documenting the software and hardware components of the solution; and selecting, collecting, analyzing, and reporting performance data related to the products developed and processes implemented. (CONOPS Pg. 32 SELI 13)

Execute task, project, and/or program responsibilities for cost, schedule, and performance (IPT Handbook Pg. 4 SELI 13, 18)

Each IPT shall have a designated leader who is accountable for the cost, schedule, performance, and risk of the IPT. (IPT Handbook Pg. 6 SELI 13, 18)

Department of Navy (DON) life cycle management organization methodology will employ IPTs that will manage and integrate critical processes ensuring that products optimize performance and long-term cost tradeoffs across all equipment, weapon, and information technology systems, and organizational sub-elements. (IPT Handbook Pg. B-1 SELI 13)

This determination involves defining the work request as one or more projects and assigning projects to IPTs; ensuring that project scope and resource requirements

are understood and documented; and engaging all involved parties in scheduling, estimating, and accepting the resulting project. (CONOPS Pg. 26 SELI 14)

With Corporate Operations the IPT manages System Administrators (SAs) and Memorandums of Understanding (MOUs) and plans for project-specific resources and administrative services. (CONOPS Pg. 26 SELI 14)

Resources may include personnel, facilities, IT infrastructure, and other resources required to execute the IPT request. (CONOPS Pg. 11 SELI 11, 14)

For those projects which have, or develop supplemental plans to address in detail any of the below areas (e.g., the project has or will develop a separate Risk Management Plan to identify, classify, categorize, and mitigate project risks), that section of the PMP will contain a reference to the more detailed plan (e.g., The project's Risk Management Plan (document ID xxx) provides detailed information on the project's risk identification and mitigation strategy). (IPT Handbook Pg. 19 SELI 15)

The IPT leverages the ISEA service desk to provide support services, system administration, and provisioning that includes multi-tier support, troubleshooting, and training. The process includes analysis to determine the type and scope of effort required: hardware or software maintenance or documentation updates. (IPT Handbook Pg. 36 SELI 15)

The collective IPT must review and finalize team documentation, submit documentation for approval to the next higher level IPT, and commit to the approved documentation. Documentation, which may be included in review and finalized by the team members, includes the IPT's Charter, PMP, Risk Management Plan, Measurement and Analysis Plan, budget allocations, schedule, performance parameters, project milestones, and Quality Assurance Plan , among others pertinent to the IPT. (IPT Handbook Pg. 21 SELI 15)

With Finance, the IPT performs business case analysis, models and refines original cost estimates, ensures business and financial compliance, and prepares funding documents. (CONOPS Pg. 27 SELI 16)

Effectively monitoring and controlling requires capturing the earned value (EV) of work performed, actual costs (AC) of work performed, and planned value (PV) of work scheduled for the measuring period. (CONOPS Pg. 29 SELI 16, 18)

The IPT Lead works with IPT members to iteratively refine customer requirements, cost estimates, resource projections, and update P2MC and Navy ERP (CONOPS Pg. 31 SELI 16)

Execute task, project, and/or program responsibilities for cost, schedule, and performance (IPT Handbook Pg.4 SELI 9, 16, 18)

IPT members or CMoI shall perform their work in accordance with cost, schedule, performance, and risk parameters set by the IPT Lead utilizing common work processes and the operational policies, procedures, and standards of the competency. (IPT Handbook Pg. 22 SELI 9, 16, 18)

Project Manager

The purpose of PM is to manage cost, schedule, and performance of product or service delivery based on an established set of requirements; establish and maintain a group of plans that define project activities execution; provide understanding of the project progress; and take appropriate corrective actions when project performance deviates significantly from the project plan. (CONOPS Pg. 29 SELI 9, 16, 18)

Table 7: Stakeholder Analysis

Active Stakeholder (User)	***Concerned SELI(s)***
COMMAND SENIOR LEADERSHIP STAFF	#12 - Process Compliance Trends
SSC-A EXECUTIVE OFFICER	#12 - Process Compliance Trends
CODE 01B DIRECTOR OF MANAGEMENT OPERATIONS	#9 - Risk Exposure Trends (Cost & Schedule) #12 - Process Compliance Trend #13 - Technical Measurement Trends #16 - System Affordability Trends #18 - Schedule and Cost Pressure Trends
CODE 01E DIRECTOR OF INTEGRATION AND EFFICIENCY	#12 - Process Compliance Trends
CODE 01I INSPECTOR GENERAL	#9 - Risk Exposure Trends (Cost & Schedule) #10 - Risk Treatment Trends #12 - Process Compliance Trend
BUSINESS PORTFOLIO	#9 - Risk Exposure Trends (Cost & Schedule)

	#12 - Process Compliance Trends #13 - Technical Measurement Trends #14 - Facility Equipment Availability #16 - System Affordability Trends #18 - Schedule and Cost Pressure Trends
BUSINESS PORTFOLIO MANAGER (BPM)	#9 - Risk Exposure Trends (Cost & Schedule) #11 - Systems Engineering Staffing and Skills Trends #14 - Facility Equipment Availability #16 - System Affordability Trends #18 - Schedule and Cost Pressure Trends
DEPUTY PORTFOLIO MANAGER (DPM)	#9 - Risk Exposure Trends (Cost & Schedule) #16 - System Affordability Trends #18 - Schedule and Cost Pressure Trends
PORTFOLIO SYSTEMS ENGINEER (PSE)	#1 - Requirements Trends #4 -Requirements Validation Trends #5 - Requirements Verification Trends #12 - Process Compliance Trends #17 - Architecture Trends
SUBPORTFOLIO LEAD (SPL)	#9 - Risk Exposure Trends (Cost and Schedule) #10 - Risk Treatment Trends #11 - Systems Engineering Staffing and Skills Trends #13 - Technical Measurement Trends #14 - Facility Equipment Availability #15 - Defect or Error Trend Specification (Artifact Documentation) #16 - System Affordability Trends #18 - Schedule and Cost Pressure
INTEGRATED PRODUCT TEAM (IPT) LEAD	#1 - Requirements Trends #2 - System Definition Change Backlog Trends #3 - Interface Trends #4 - Requirements Validation Trends #5 - Requirements Verification Trends #9 - Risk Exposure Trends (Cost and Schedule) #10 - Risk Treatment Trends #11 - Systems Engineering Staffing and Skills Trends #12 - Process Compliance Trend #13 - Technical Measurement Trends #14 - Facility and Equipment Availability #15 - Defect or Error Trends (Artifact Documentation) #16 - System Affordability Trends #18 - Schedule and Cost Pressure Trends

IPT TECHNICAL LEAD	#6 - Work Product Approval Trends #9 - Risk Exposure Trends (Cost and Schedule) #10 - Risk Treatment Trends #11 - Systems Engineering Staffing and Skills Trends #14 - Facility and Equipment Availability Trends #15 - Defect or Error Trends Specification (Artifact Documentation)
5.0 COMPETENCY	#11 - Systems Engineering Staffing and Skills Trends #12 - Process Compliance Trend #14 - Facility Equipment Availability #16 - System Affordability Trends
TIER 1 LOCAL COMPETENCY LEAD (LCL)	#12 - Process Compliance Trends
LEAD SYSTEMS ENGINEER (LSE)	#7 - Review Action Closure Trends #12 - Process Compliance Trends #17 - Architecture Trends
CONTINUOUS PROCESS IMPROVEMENT (CPI) LEAD	#1 - Requirements Trends #2 - System Definition Change Backlog Trends #4 - Requirements Validation Trends #5 - Requirements Verification Trends #12 - Process Compliance Trend
PROCESS OWNER	#12 - Process Compliance Trends #13 - Technical Measurement Trends
PROCESS MANAGER	#12 - Process Compliance Trends #13 - Technical Measurement Trends
COMPETENCY ADMINISTRATIVE SUPPORT	#1 - Requirements Trends #4 - Requirements Validation Trends #5 - Requirements Verification Trends
TIER 2 COMPETENCY LEAD (CL)	#1 - Requirements Trends #4 - Requirements Validation Trends #5 - Requirements Verification Trends #11 - Systems Engineering Staffing and Skills Trends #13 - Technical Measurement Trends #14 - Facility and Equipment Availability
TIER 3 COMPETENCY MANAGER (CM)	#1 - Requirements Trends #4 - Requirements Validation Trends #5 - Requirements Verification Trends #11 - Systems Engineering Staffing and Skills Trends #18 - Schedule and Cost Pressure
TIER 4 COMPETENCY SUPERVISOR (CS)	#1 - Requirements Trends #4 - Requirements Validation Trends

	#5 - Requirements Verification Trends #11 - Systems Engineering Staffing and Skills Trends
FIRST-LINE SUPERVISOR	#11 - Systems Engineering Staffing and Skills Trends #13 - Technical Measurement Trends
CONTRACTING OFFICER`S REPRESENTATIVE (COR)	#11 - Systems Engineering Staffing and Skills Trends #13 - Technical Measurement Trends #14 - Facility and Equipment Availability Trends #16 - System Affordability Trends
Integrated Product Team	#1 - Requirements Trends #2 - System Definition Change Backlog Trends #4 - Requirements Validation Trends #5 - Requirements Verification Trends #8 - Technology Maturity Trends #9 - Risk Exposure Trends (Cost and Schedule) #11 - Systems Engineering Staffing and Skills Trends #12 - Process Compliance Trend #13 - Technical Measurement Trends #14 - Facility and Equipment Availability Trends #15 - Defect or Error Trend Specification (Artifact Documentation) #16 - System Affordability Trends #18 - Schedule and Cost Pressure Trends
Project Manager	#9 - Risk Exposure Trends (Cost and Schedule) #16 - System Affordability Trends #18 - Schedule and Cost Pressure

APPENDIX D. RESEARCH QUESTIONS AND ANSWERS

Working with the stakeholders' requirements and current state of technology, the SEHV team developed system engineering research questions that guided the research and the system conceptual design. These questions formed the basis for understanding stakeholders' needs and system goal of this project.

1. Data Sources

- Which tools and supporting processes capture the data elements needed to ingest into the SEHV solution?

  Answer. Tools such as NERP, JIRA, IBM Rational, TAA tool, Demand Signal Tool, TWMS, Risk Exchange, and the Defense Civilian Personnel Data System (DCPDS) would support Risk Exposure Trends, SE Staffing and Skills Trends, Process Compliance Trends, Technical Measurement Trends, and System Affordability Trends.

- What engineering tools are being leveraged?

  Answer. NERP, Risk Exchange, DCPDS, IBM Rational, JIRA, TAA, Demand Signal Tool, and TWMS would be leveraged to support SELI trending. SELIs not expanded on within this capstone report would need additional SE / SE management tools or applications to be leveraged.

- What data sources are available?

  Answer. Data elements gathered from tools such as NERP, JIRA, IBM Rational, TAA tool, Demand Signal Tool, TWMS, Risk Exchange, and DCPDS would support Risk Exposure Trends, SE Staffing and Skills Trends, Process Compliance Trends, Technical Measurement Trends, and System Affordability Trends.

- What data elements are needed?

  Answer. Data elements are listed within Chapter IV under each selected SELI.

- What tool data is most dependable or valuable?

  Answer. Recommended data elements listed in Chapter IV under each SELI would be the most valuable to display trending data over time.

2. Data Collection

- How is data currently being captured?

  Answer. Data is currently being captured in SE / SE management Tools that SSC-A is using; however, this data is not being gathered in a consolidated location to produce trends of SELI. Limited manual data call processes take place currently to capture data to determine project health and status.

- How will the automatic collection work?

  Answer. Automatic collection would have to be done by middleware software that collects necessary data elements from the SE / SE management tools and stored in a database where historical and current SELI trends would be able to be produced. Automatic data collection is part of the SEHV methodology which includes capture, store, analyze, and display. Physical architecture specifies how data will be captured in future work.

- If the data cannot be collected automatically, can the SELI data elements be collected on some sort of schedule?

  Answer. Chapter V recommends that SE / SE management would have to utilize mandated tools at least once a month to have up to date information. Data collection should be performed once a month to have current information. An automated process is preferred to reduce recurring loops and human error.

- How easily can one collect any specific piece of data?

  Answer. Future work would have to include analyzing SE / SE management tools more in depth to see how easily it would be to collect specific pieces of data. Transforming the format of this data may need to take place in order to be compatible with the SEHV system.

3. Data Storage

- How are these data elements (individual pieces of data) related to one another?

  Answer. Data elements for SELI trends were found to be related to each other in different ways depending on the specific data elements in question. Data elements from NERP can display the amount of man-hours used for a particular SE activity which would support SE Staffing and Skills trends as well as System Affordability trends. Data elements tied to Technical Measurement trends would also fuel Risk Exposure trends. Overall these data elements for SELIs are related by producing visual trends that

would display the overall health of a project with respect to SE / SE management activities.

- What questions will be asked of the data?

  Answer. Per the SELI Guide version 2.0, data elements for Risk Exposure trends would pose questions such as:

  - *Is the risk exposure going to impact the system solution?*
  - *Is the SE effort managing the exposure successfully?*

  Per the SELI Guide version 2.0, data elements for SE Staffing and Skills trends would pose questions such as:

  - *Is SE effort being applied to the project activities consistent with proven organizational or industry practice?*
  - *Do the staff members have the appropriate skills and experience to achieve assigned tasks?*
  - *Is the personnel turnover a reason for concern?*

  Per the SELI Guide version 2.0, data elements for Process Compliance trends would pose questions such as:

  - *To what extent are the SE processes in place and being used on the project?*

  Per the SELI Guide version 2.0, data elements for Technical Measurement trends would pose questions such as:

  - *To what extent are the performance parameters feasible and being achieved per plan?*

  Per the SELI Guide version 2.0, data elements for System Affordability trends would pose questions such as:

  - *Is the SE effort progressing towards a system that is affordable for the stakeholders?*

- How long will the historical data need to be stored?

  Answer. The more historical data available, the more ability to discern problematic trends leadership will have. If file size of the data elements do not take up a lot of database / disk space, all of the data should be saved within a central repository. A recommendation would be to store enough to show a project's trends to see improvements or declines in certain SE / SE management areas.

4. Data Analysis

- Can a process be constructed to avoid data calls?
  Answer. The generic SEHV methodology, as shown in Chapter V, reduces manual processes within data calls by adding automated processes. This will reduce disruption amongst SE / SE management with regards to data calls.

- What calculations need to be performed on the data elements?
  Answer. Adding values of data elements which form graphical trends over time is necessary for SELIs. These computed values should be in the form of arrays of numbers that correlate with time values. The x-axis would primarily be time where the y-axis would show the value of the planned vs. actual measure of each SELI. Specific data element information is located within Chapter IV.

- What trending patterns are being looked for in the data?
  Answer. Deviations from planned values can indicate potential issues especially when deviations are recurring. Staying within a set range of acceptable values would demonstrate a consistent well-managed project with respect to SE / SE management. Specific recommended methodologies for SELI trending are shown within Chapter IV.

5. Data Display

- What visualizations best represent the data?
  Answer. Line graphs and bar graphs represent the data effectively for SELIs. Displaying trends of SELIs to see planned vs. actual values would show if a project is on track. Deviations would trigger leadership to intervene in order to assist with getting the project back on track.

6. SEHV Stakeholders

- Who are the stakeholders that need to view these SELIs?
  Answer. Stakeholders were matched with SELIs using the descriptions of roles within the SSC-A CAO CONOPS and IPT Lead Handbook. The results are shown in Appendix C.

7. SELIs

- What are the top SELIs that will provide the most insight to leadership for determining how well the SE project is going?
  Answer. The top SELIs are shown in Chapter II within the SELI down select process. These SELIs were matched to stakeholders from descriptions of roles within the SSC-A CAO CONOPS and IPT Lead Handbook.

- Which SELIs do the stakeholders find most-useful?
  Answer. Using the SSC-A CAO CONOPS and IPT Lead Handbook as a basis for stakeholder descriptions, Appendix C depicts which stakeholders are aligned with SELIs. All 18 SELIs are important and necessary to monitor project status with respect to SE / SE management.

8. Other Topics

- What is good systems engineering / management? Is it similar to good project management with ensuring the SEHV system functions satisfy stakeholder requirements?
  Answer. Good SE / SE management practices are shown by applying and monitoring SE practices consistently on a project. This is similar to good PM by frequently performing and monitoring activities that affect cost, schedule, and performance parameters.

- How are other similar commands monitoring SEHV? (Ex. SSC-PAC, NavFac, NavAir, Army Corps., AF ESC)
  Answer. NAVAIR uses SELI methodology on their ACAT II airplane development program. NAVAIR developed the ALI tool to support displaying SELIs for their program. SEHV will be used amongst multiple programs and projects to depict the command's overall health with respect to SE / SE management.

- How much will it cost to collect SELI data elements?
  Answer. Cost analysis of the SEHV concept is shown in Chapter VI.

- How long should it take to obtain a required visualization?
  Answer. Once the SEHV system is in place, automation of manual processes such as data collection, and trending can support visualization instantly. As long as monthly use of mandated SE / SE

management tools are being utilized amongst projects, fresh up-to-date data would be available for viewing.

- How many metrics or trends should be viewed?
  Answer. Descriptions of the selected SELIs within Chapter IV elaborate on specific metrics and trends that should be viewed.

APPENDIX E. SUPPLEMENTALS

The following items are supplemental to this report and are available at the Dudley Knox Library of the Naval Postgraduate School.

- SEHV Operational Views
- Innoslate IDEF0 Models
- SSC-A Joint Framework
- ExtendSim Models
- Cost Spreadsheet

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Bausman, Karen and John Colombi. 2009. *Preparing for the Future of Systems Engineering.* Defense Acquisition, Technology and Logistics. http://www.dau.mil/pubscats/PubsCats/atl/baus_jf09.pdf.

Blanchard, Benjamin S., and W. J. Fabrycky. 2011. *Systems Engineering and Analysis*. London: Pearson.

Buede, Dennis M. 2008. *The Engineering Design of Systems: Models and Methods*. Hoboken, New Jersey: Wiley. Edited by Andrew P. Sage.

Carney, David J., and Patricia A. Oberndorf. 1997. "The Commandments of COTS: Still in Search of the Promised Land." Software Engineering Institute, Carnegie Mellon University, May 1, 2011. https://acc.dau.mil/adl/en-US/24403/file/2848/ten_comm.pdf.

Clark, Betsy, and Brad Clark. 2007. "Added Sources of Costs in Maintaining COTS-Intensive Systems." *CrossTalk, The Journal of Defense Software Engineering* 5:1-5.

Clements, Jessica, Elizabeth Angeli, Karen Schiller, S. C. Gooch, Laurie Pinkert, and Allen Brizee. 2011. "General Format." *The Purdue OWL*. http://owl.english.purdue.edu/owl/resource/717/13/.

CMMI Institute. 2014. *Capability Maturity Model Integration.* http://whatis.cmmiinstitute.com/training/fundamentals-cmmi. Accessed September 30.

———. 2014. *Fundamentals of Capability Maturity Model Integration.* http://whatis.cmmiinstitute.com/training/fundamentals-cmmi. Accessed September 30.

Cook, David A. 2007. "Issues to Consider Before Acquiring COTS." *CrossTalk, The Journal of Defense Software Engineering* 4: 1–4.

Department of Defense - U.S. Army. 2005. "Practical Software and Systems Measurement Objective Information for Decision Makers." Technical report. Picatinny Arsenal, New Jersey: U. S. Army. http://www.ieee.org.ar/downloads/card-2005-psm-2.pdf

Eusgeld, Irene, Felix C. Freiling, and Ralf Reussner. 2008. "Dependability Metrics - Lecture Notes in Computer Science 4904." *Commenced Publication in 1973.* Edited by Gerhard Goos, Juris Hartmanis and Jan van Leeuwen. Germany: Springer-Verlag Berlin Heidelberg.

Extend Sim. 2002 - 2009. *Extend Sim User Guide Download.* Imagine That, Inc. http://www.extendsim.com/downloads/manuals/support_manuals_dl.html.

Green, John M. 2013. Systems Assessment: Introduction to the Analytic Hierarchy Process. Naval Postgraduate School. Monterey. SE3303. Accessed October 20.

Highcharts. 2014. *Make your Data Come Alive.* www.Highcharts.com. Accessed August 29.

INCOSE Measurement Working Group. 2010. *Systems Engineering Measurement Primer: A Basic Introduction to Measurement Concepts and Use for Systems Engineering.* 2.0. INCOSE-TP-2010-005-02: INCOSE.

INCOSE SE Working Group. 2010. *Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities.* Edited by Cecilia Haskins, Kevin Forsberg, Michael Krueger, David Walden and Douglas Hamelin. INCOSE"TP"2003"002"03.2.

INCOSE Technical Board. 1995. *Metrics Guidebook for Integrated Systems and Production Development.* Guidebook, INCOSE-TP-1995-002-01: INCOSE Measurement Technical Committee.

INCOSE International Council on Systems Engineering, Lean Aerospace Intiative, Systems Engineering Advancement Research Initiative, and and PSM. 2010. *Systems Engineering Leading Indicators Guide.* Edited by Garry Roedler, Donna H. Rhodes, Howard Schimmoller and Cheryl Jones. Vol. 2.0.

———. 2007. *Systems Engineering Leading Indicators Guide.* Edited by Garry Roedler and Donna H. Rhodes. Vol. 1.0.

Institute of Electrical and Electronics Engineers (IEEE). 1998. *IEEE Standard for Functional Modeling Language - Syntax and Semantics for IDEF0.* Software Engineering Standards Committee of the IEEE Computer Society.

———. 2005. 1220–2005 - IEEE Standard for Application and Management of the Systems Engineering Process

———. 2007. *Systems and Software Engineering - Measurement Process.* Software and Systems Engineering Standards Committee

———. 2008. *Systems and Software Engineering - System Life cycle Processes.* 2nd. International Organization of Standards (ISO).

International Business Machines. 1994, 2014. *IBM Rational Quality Manager Software Tool.* United States, http://www-03.ibm.com/software/products/en/ratiqualmana.

International Organization of Standards (ISO). 2012. “ISO 9000 Quality Management Principles.” *ISO.org.* http://www.iso.org/iso/qmp_2012.pdf.

Manning, Berton. 2014. *AcqNotes: A Simpler Source of DOD Acquisition Knowledge for Aerospace.* http://www.acqnotes.com/Career%20Fields/ Technical%20Performance%20Measurement.html. Accessed September 30.

Montgomery, Paul, and Ron Carlson. 2010. “*Systems Engineering Applied Leading Indicators’ Enabling Assessment of Acquisition Technical Performance*.” https://calhoun.nps.edu/public/bitstream/handle/10945/33585/NPS-AM-10-175.pdf?sequence=1.

Navy ITSMO Service Quality Management Practice. 2014. “*Navy ITSMO, IT Performance Management Guide*.” Guide.

Office of Inspector General. n.d. “DIMHRS IG Audit.” Audit Report

Page, Larry, and Sergey Brin. 1998. *Google.* www.google.com

Phillips, Barbara C., and Susan M. Polen. 2002. “*Add Decision Analysis to Your COTS Selection Process.” CrossTalk, The Journal of Defense Software Engineering* 5:1-5.

Rational, Software Development Company. 1998. “Rational Unified Process: A Best Practices Approach.” White Paper, Cupertino and Lexington.

Redshaw, Mary. 2006. *A New Systems Engineering Model and an Old, Familiar Friend.* Defense Acquisition, Technology and Logistics.

Rhodes, Donna H., Ricardo Valerdi, and Garry J. Roedler. 2008. “*Systems Engineering Leading Indicators for Assessing Program and Technical Effectiveness*.” Preprint of article accepted for publication in Systems Engineering. (Wiley Periodicals, Inc. 2008). http://seari.mit.edu/documents/preprints/RHODES-SE071205.pdf.

Roedler, Garry J., and Cheryl Jones. 2005a. *Technical Measurement: A Collaborative Project of PSM, INCOSE, and Industry.* Technical Report, INCOSE-TP-2003-020-01.

———. 2005b. *Technical Measurement.* Guide.

Roedler, Garry, and Donna H. Rhodes. 2007.”SE Leading Indicators Guide.” *version 1. Massachusetts Institute of Technology, INCOSE, and PSM.*

Roedler, Garry, Donna Rhodes, Cheryl Jones, and Howard Schimoller. 2004. *SE Leading Indicators Meeting.*

Saaty, Thomas L. and Kirti Peniwati. 2008a. *Group Decision Making: Drawing out and Reconciling Differences.* Pittsburgh, Pennsylvania: RWS Publications.

———. 2008b. *Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World.*

Sankar, Vijay. 2013. *The practical applications of traceability Part 1: What's really going on when you decompose a requirement?* https://www.ibm.com/developerworks/community/blogs/requirementsmanagement/entry/the_practical_applications_of_traceability_part_1_what_s_really_going_on_when_you_decompose_a_requirement?lang=en.

SPAWAR Atlantic CPI ESG. 2014. *CPI Executive Steering Group.* https://wiki.spawar.navy.mil/confluence/pages/viewpage.action?pageId=54485783. Accessed October 20.

SPAWAR Atlantic. 2014. Full Diagram: *Joint Framework.* https://wiki.spawar.navy.mil/confluence/x/LQISB. Accessed October 13.

SPAWAR SYSCEN- Atlantic. 2014. *Integrated Product Team Handbook.* Charleston: 6.0 Program and Project Management Competency. Accessed October 25.

SPAWAR Systems Center-Atlantic. 2014. *Competency Aligned Organization and IPT Handbook.* version 2.1. Charleston.

Statz, Joyce. 2005. *Measurement for Process Improvement.* Technical Report, Practical Software and Systems Measurement.

Stoneburner, Gary, Alice Goguen, and Alexis Feringa. 2002. "Risk Management Guide for Information Technology Systems." National Institute of Standards and Technology. http://csrc.nist.gov/publications/nistpubs/800-30/sp800-30.pdf.

Systems Engineering Research Center. 2009. *Early Identification of SE Related Program Risks Opportunities for DOD Systems Engineering Transformation via SE Effectiveness Measures and Evidence-Based Reviews.* Edited by Alfred Brown, et al.

University of Chicago. 1982, 1993, 2003. *The Chicago Manual of Style Online Author-Date.* University of Chicago Press. http://www.chicagomanualofstyle.org/tools_citationguide.html.

University of Chicago. 2006, 2007, 2010. *The Chicago Manual of Style Author-Date.* University of Chicago Press. http://www.chicagomanualofstyle.org/tools_citationguide.html.

Ugone, Mary L. 2010. *"Results in Brief: Acquisition Decision Memorandum for the Defense Integrated Military Human Resources System."* http://www.dodig.mil/audit/reports/fy10/10-041redacted.pdf.

Wikipedia. 2014a. s.v. *Analytical Hierarchy Process* http://en.wikipedia.org/w/index.php?title=Analytic_hierarchy_process&oldid=620928150. Accessed October 30.

———. 2014b. s.v. *Capability Maturity Model Integration.* http://en.wikipedia.org/wiki/Capability_Maturity_Model_Integration. Accessed September 30.

———. 2014c. s.v. *Process Management.* http://en.wikipedia.org/wiki/Process_management Accessed October 17.

———. 2014d. s.v. *Rational Quality Manager.* http://en.wikipedia.org/wiki/Rational_Quality_Manager. Accessed October 25.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California