



Sponsor: DoD
Dept. No.: E143, E146
Contract No.: FA8702-13-C-0001
Project No.: 03135000-EE

The views, opinions and/or findings contained in this report are those of The MITRE Corporation and should not be construed as an official government position, policy, or decision, unless designated by other documentation.

Approved for Public Release; Distribution Unlimited 13-2314

©2013 The MITRE Corporation.
All rights reserved.

Location: Bedford, MA

Domain Systems Engineering Architecting & Analysis (DSEA&A) Start-Up Guide

**Murray Daniels
Jay Scarano**

April 2013

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, 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. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE APR 2013		2. REPORT TYPE		3. DATES COVERED 00-00-2013 to 00-00-2013	
4. TITLE AND SUBTITLE Domain Systems Engineering Architecting & Analysis (DSEA&A) Start-Up Guide				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) MITRE Corporation, 202 Burlington Road, Bedford, MA, 01730				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Acknowledgments

The authors would like to thank: Eric Skoog and Dave Genovese for their original efforts in describing the methodology; Ray Modeen, Laura Ricci, and Joe Bradley for their pioneering efforts at execution; all the “sprinters” who have contributed to lessons learned and further illuminated the process; and Colonel David Crean for providing the opportunity to write it all down.

Table of Contents

1	Introduction – The What, Why, and How of DSEA&A.....	1-1
1.1	Purpose of this Document.....	1-1
1.2	Audience	1-1
1.3	Scope of this Document	1-1
2	Essential Questions	2-1
2.1	What is a Domain?.....	2-1
2.2	What is Domain Systems Engineering Architecting & Analysis (DSEA&A)?	2-2
2.3	Who does DSEA&A?	2-4
2.4	Why should I do DSEA&A?.....	2-4
2.5	What is a “DSEA&A Sprint?”	2-4
2.6	How are Sprints Governed and Managed?	2-5
2.7	What are Some Examples of Sprints?.....	2-6
3	How do I do DSEA&A?	3-1
3.1	Step 1 – Setup the Effort.....	3-2
3.2	Step 2 – Develop the Architecture/Model	3-5
3.3	Step 3 – Perform the Analysis	3-5
3.4	Step 4 – Identify and Document COAs	3-6
3.5	Step 5 – Manage and Evolve the Effort	3-8
4	Summary.....	4-1
Appendix A	References	A-1
Appendix B	Bibliography.....	B-1
Appendix C	Acronyms	C-1
Appendix D	Affordability, Efficiency, and Effectiveness.....	D-1
Appendix E	Potential DSEA&A Artifacts	E-1
Appendix F	DSEA&A Sprint Terms of Reference Typical Contents	F-1
Appendix G	Stakeholder Engagement Metrics.....	G-1

List of Figures

Figure 1 – Domain Outcomes Supported by DSEA&A	2-3
Figure 2 – DSEA&A Management Process.....	2-5
Figure 3 – Domain Systems Engineering, Architecture, & Analysis	3-1
Figure 4 – COA Example	3-7
Figure 5 – Affordability, Efficiency, and Effectiveness.....	D-1

This page intentionally left blank.

1 Introduction – The What, Why, and How of DSEA&A

The Air Force Life Cycle Management Center (AFLCMC) Hanscom Operating Location (Hanscom-OL) (formerly known as Electronic Systems Center or ESC) implemented a methodology called Domain Systems Engineering, Architecting and Analysis (DSEA&A) to enable the identification and resolution of domain-level problems or opportunities related to affordability, efficiency, and effectiveness (AE&E). The goal of DSEA&A, also referred to as domain analytics (DA), is to consider and assess a set of potential solutions to resolve problems identified by one or more domain stakeholders. The scope of a DSEA&A effort can be wholly contained within a Program Executive Officer's (PEO) portfolio or can span multiple PEOs' portfolios. DSEA&A was developed in response to AF higher headquarters' desires to identify and deliver cross-cutting, affordable solutions in a timely manner.

1.1 Purpose of this Document

This document provides a high-level introduction to DSEA&A. It highlights one way to do DSEA&A based on lessons learned in applying these concepts to acquisitions at the Hanscom Operating Location (Hanscom-OL) of the AF LCMC. This is a set of guidelines and not a prescription. DSEA&A builds on traditional systems engineering, architecture, and analysis methodologies. Individual DSEA&A activities must be considered relative to the domain and problem at hand and should be tailored as needed.

1.2 Audience

This document is targeted primarily to DSEA&A practitioners aka "domain engineers." It is also suitable as background information for a wide range of audiences including leadership, policy makers, users, and acquisition personnel. We assume that you are new to DSEA&A but have some exposure to traditional systems engineering.

1.3 Scope of this Document

This document addresses only the additional effort required to do DSEA&A. It does not address how to do traditional systems engineering, basic architecting and analysis, system implementation, program management, etc. The reader is presumed to have a basic understanding of these related areas.

2 Essential Questions

2.1 What is a Domain?

DSEA&A, as its name implies, is focused on the concept of a “domain.” A domain is a flexible concept. We often hear about “the air domain,” “the ISR domain,” or “the cyber domain,” but there are many types of domains.

Merriam-Webster [10] defines “domain” as:

- ...
- 2: a territory over which dominion is exercised
- 3: a region distinctively marked by some physical feature <the *domain* of rushing streams, tall trees, and lakes>
- 4: a sphere of knowledge, influence, or activity <the *domain* of art>
- ...

The term domain, as used herein, refers to a bounded part of some problem space having an identifiable controlling individual or group of individuals authorized to make decisions.

For the purposes of DSEA&A:

- domains can be based on:
 - a common purpose
 - mission area characteristics (e.g., C2, ISR, cyber, business operations)
 - geo-spatial considerations (e.g., land, sea, air, space)
 - common functional characteristics (e.g., communications and networking infrastructure, sensor technology)
- may encompass a set of common capabilities¹ and (for information-based domains) common data
- are generally supported by many acquisition programs across multiple acquisition organizations (and a single acquisition program might support multiple domains)²
- can be “big” or “small” (i.e., vary widely in breadth and depth)
- can be decomposed into “sub-domains” and can conversely be part of a larger domain (i.e., sub-domains may inherit certain attributes of their parent domain)
- can cross other domains (e.g., the “air domain” may include some, but not all, elements of the ISR domain; the intersection might be called “the air ISR domain” and would by definition be a sub-domain of each)

¹ A capability includes multiple aspects to include people, processes, and tools (materiel) and is focused on achieving a measurable effect.

² A domain may be scoped so as to be wholly addressed by a single acquisition program in which case DSEA&A is essentially traditional SE applied to the scope of the domain versus the system being acquired.

- can be associated with zero, one, or more Systems of Systems (SoSs) [9] (similarly, a given SoS may span multiple domains)

When scoping a domain, you need to identify a “domain authority” – i.e., some individual or group who can make decisions about relevant aspects of the domain (e.g., planning, acquisition, operations) and who has some degree of accountability for those aspects. The domain authority may be, for example, a PEO or Service Acquisition Executive or a similar representative from the requirements or strategic planning community. Identifying a domain authority can be especially challenging in cases where the domain is large and/or cross-cutting and several PEOs or Core Function Lead Integrators (CFLIs) may be involved in a decision.

Some domains display a mix of defining characteristics. For example, “cyber” can be thought of as both functional and mission-oriented in nature.

2.2 What is Domain Systems Engineering Architecting & Analysis (DSEA&A)?

DSEA&A is an attempt to address one or more problems associated with a domain – or, alternatively, to achieve some desired outcome³. DSEA&A efforts are typically exploratory, agile, and time-bounded in nature. They explore both the problem space and the solution space, attempt to adjust to the findings that result from this exploration, and follow an incremental approach.

DSEA&A is a mix of synthesis and analysis activities. The domain engineer creates (synthesizes) a high-level representation (an architectural model⁴) of the domain to include both the problem space and the solution space. They refine this representation by analyzing the problem space and iterating potential solutions within the context of a tradespace⁵. They identify issues, risks, and opportunities in the existing architectures, designs, or CONOPS associated with the domain⁶ (to include those pertaining to related programs). Finally, they assess each potential solution, based on pre-defined assessment criteria. This leads to information that decision makers can use in choosing a specific solution.

The representation of the domain is key. The representation should highlight key aspects and support effective situational awareness as well as exploration and analysis of current (“as-is”) and alternative future (“to-be”) states. The DoD Architecture Framework (DoDAF) [5] provides a degree of rigor for developing domain architectures (models), but we want to stress some important points:

³ DSEA&A efforts should be focused on achieving some desired outcome associated with the domain. An outcome is a change in the state of the domain. One kind of outcome is the resolution of some known issue or problem, but outcome-directed thinking is a mindset that focuses on achieving goals vs (just) fixing problems. See [8] for a discussion of the difference between outcome-directed thinking and problem-directed thinking.

⁴ DSEA&A can be thought of as supporting Model-Based Systems Engineering (MBSE) [6]

⁵ A tradespace identifies the range of solution parameters that can be varied to achieve various effects. This can include various aspects of a materiel solution as well as other DOTMLPF aspects.

⁶ Such issues, risks, and opportunities may only be apparent when viewed from the scope of the domain.

- The architecture must support the analysis (not just be a set of visualizations).
- The architecture is the underlying structured data, e.g., assets, missions, threats, information exchanges, supporting systems and their relationships, and not the visualizations of that data. Thus, it is more important to have and understand the architectural data than it is to formalize the data in specific views.
- The architecture should reflect the actual current situation rather than an idealized situation that might, for example, better align to current vision or policy.
- The architecture is a model of both the problem (requirements space) and potential solution(s) (technology space).
- The architecture reflects the domain and is scoped to a specific purpose (desired outcome or problem resolution). It is generally not as detailed as a typical program-level architecture.
- The to-be architecture should support anticipated operational scenarios.

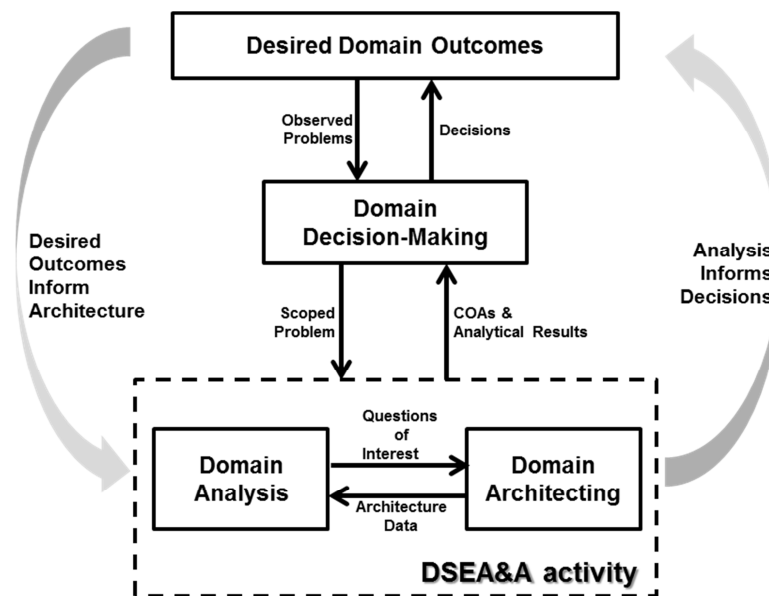


Figure 1 – Domain Outcomes Supported by DSEA&A

Figure 1 depicts the context for DSEA&A at a high-level. DSEA&A is framed by the hashed box. It is driven from the top by one or more desired domain outcomes. The domain engineer represents the domain in the domain architecture. This then serves to support the domain analysis focused on specific questions of interest derived from the desired outcomes. As part of the analysis, the domain engineer identifies and assesses various alternative Courses of Action (COAs)⁷ to support decision-making⁸ related to achieving the desired outcomes.

⁷ A COA is a sequence of steps for effecting a change in the state of the domain – or, stated another way, for achieving a desired outcome.

⁸ Typical decisions include: accept a COA as defined, request additional work to refine a specified COA, reject all COAs and start over.

2.3 Who does DSEA&A?

DSEA&A requires an explicit focus on the domain in question. The domain is typically not directly associated with only a single program. In this case engineering resources are required to span more than one program. Funding for such resources might come from various sources – but that issue is not addressed here.

We will use the term domain engineer to indicate someone who performs DSEA&A. This will, by definition, include architects and analysts working at the domain-level. These individuals will, of necessity, often interact with counterparts working at the level of individual programs that relate to the domain. Some of these individuals may simultaneously have both domain and program-level engineering responsibilities (i.e., be dual-hatted).

Domain engineers interact, as appropriate, with counterparts in various fields: contracting, finance, procurement, legal, logistics, etc.

2.4 Why should I do DSEA&A?

First and foremost, you should do DSEA&A because there is desire to achieve some outcome(s) associated with a defined domain. Take a domain defined around some operational concept such as planning missions or obtaining intelligence. Such domains are typically supported by materiel acquired by more than one acquisition program – and that materiel needs to work together efficiently and effectively to help realize desired mission effectiveness. The outcome may be explicitly focused on achieving affordable support for domain operations. (The concept of Affordability, Efficiency and Effectiveness (AE&E) is described in Appendix D.) Specific outcomes in such a case might entail resolving some issue, mitigating some risk, and/or leveraging some opportunity. The outcome reflects stakeholders’ values and serves as a means for defining and measuring the success of the DSEA&A effort.

The domain engineer supports a decision (action) by one or more stakeholders related to realizing the outcome. This could include decisions related to requirements (JCIDS [1]), program planning and budgeting (PPBE [2]), acquisition (DAS [3]), and Portfolio Management (PfM). These decisions might include changes to how existing programs execute, changes to plans for future programs (e.g., strategic plans, POMs), changes to system-related operating procedures, etc.

DSEA&A strives to ensure that these decisions are based on high quality (rigorously developed, defensible) analytic results.

2.5 What is a “DSEA&A Sprint?”

DSEA&A is often amenable to execution in a somewhat agile fashion [7] via short iterative increments known as “sprints.” A DSEA&A sprint nominally takes on the order of 3 to 6

months.⁹ Every sprint should result in some measurable progress towards achieving the stated outcome, but precise sprint contents depend on the given context.

In some cases, a sequence of sprints might be warranted. Initial sprints might focus on setting up the overall effort. Subsequent sprints might focus on understanding the domain (developing the initial domain architecture), performing specific analysis against that architecture, and refining the architecture in response to the analysis. A sequence of sprints is generally shaped by intervening heading checks between each sprint.

2.6 How are Sprints Governed and Managed?

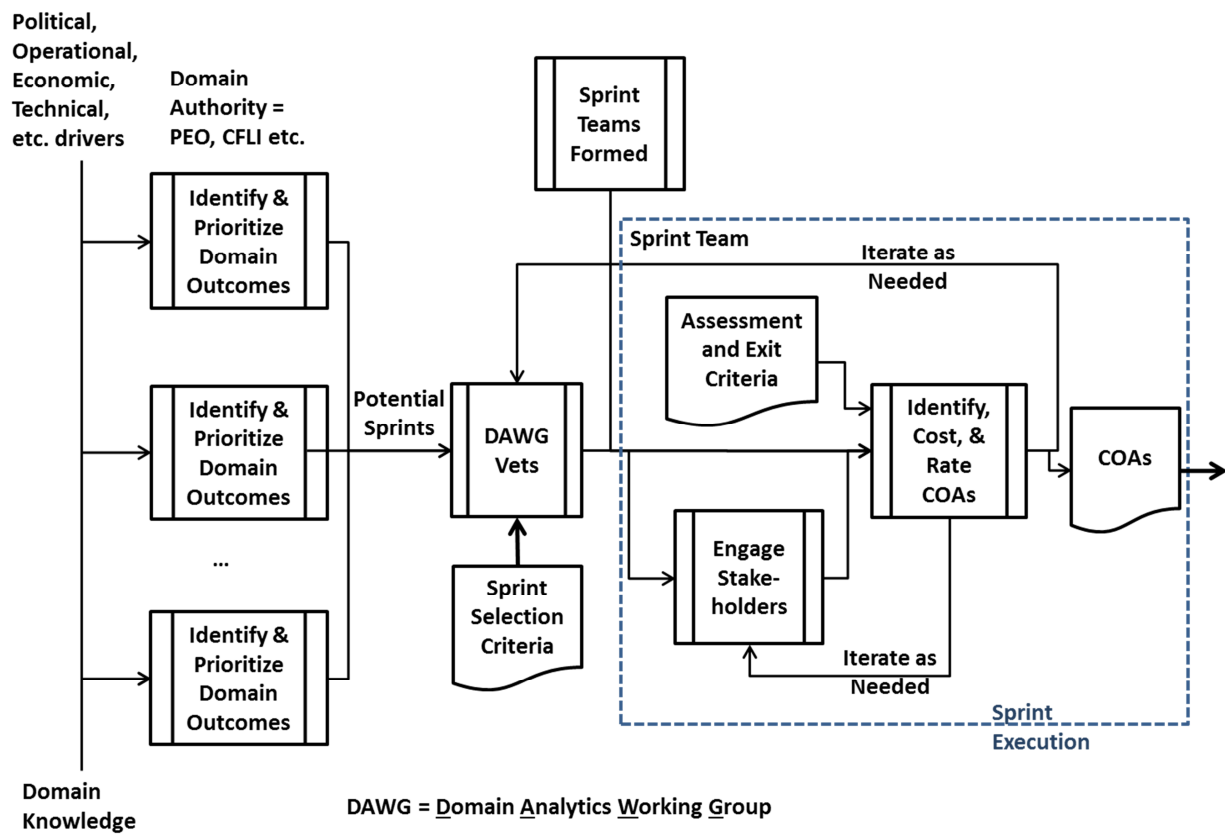


Figure 2 – DSEA&A Management Process

Sprints can be overseen and managed in a number of ways. Figure 2 shows a notional approach that can be adapted as needed. This particular approach includes a central management body – the Domain Analytics Working Group (DAWG)¹⁰– that manages the use of shared resources and promotes cross-domain coordination where appropriate. Sprints that are wholly contained within

⁹ For IT-heavy domains. Other domains might have different nominal sprint durations.

¹⁰ The DAWG concept was implemented as part of the AF LCMC Hanscom-OL experience in DSEA&A.

a single domain and/or that do not use shared resources may be managed within the domain in a similar fashion (but at a smaller scale).

The process starts with the identification and prioritization of domain outcomes by each domain. This activity is generally overseen by the domain authority and results in a set of potential sprints.

The DAWG then vets potential sprints using a set of selection criteria. This might include, among others, the timeframe for the expected impact, the number of resources required, the availability of resources, the breadth of the impact, and the anticipated value of the result.

After a sprint is approved, the sprint team is formed and executes the sprints, as described below. This includes the identification and characterization of COAs, potentially iterative refinement of those COAs with the stakeholders and the DAWG, and assessment of the COAs against a set of assessment criteria coordinated with the stakeholders. The sprint ends based on an evaluation against a set of exit criteria that is also coordinated with the stakeholders.¹¹

In addition to the above, the DAWG collects and shares lessons learned from across the sprints.

2.7 What are Some Examples of Sprints?

Here are some example sprints to consider:

Mission Planning for Network-Enabled Weapons (NEWs)

The introduction of Net-Enabled Weapons (NEWs) into the Air Force's arsenal provides additional capability but also requires additional C2 (tasking and detailed planning) effort. Net-Enabled Weapons, such as the Joint Standoff Weapon (JSOW) and Small Diameter Bomb II (SDB II), offer the potential to connect to tactical data links (TDLs) while in flight to support dynamic re-targeting and improved Battle Damage Assessment (BDA) (among others). This ongoing (as of this writing) sprint explores how to best support the tasking and planning of air missions involving NEWs. Areas of investigation include systems that support the Air Operations Center (AOC), systems that support unit-level mission planning, related data standards such as USMTF and the Air Operations Community of Interest schema, and mechanisms to support the exchange of data between the AOC and the unit-level. Current plans related to these areas may not adequately support machine-to-machine data exchange among these systems before the widespread deployment of NEWs in the AF arsenal. As a result, the tasking and planning of NEW-related air missions may require significant manual intervention with potential for delays and data entry errors.

Ubiquitous Battle Management Command & Control (μ BMC2)

Historically, unique Battle Management Command & Control (BMC2) solutions have been developed for individual sensors often without sufficient consideration for the reuse/sharing of common components or the need for interoperability among the different sensor systems. This

¹¹ Typical exit criteria might include when an acceptable COA is defined and/or when DSEA&A resources are depleted.

sprint was an investigation to determine whether coupling a BMC2 capability for new sensors would yield benefits from the perspective of AE&E. Specifically, it investigated the BMC2 needs of Global Hawk Block 40, Dismount Detection Radar (DDR), and the next generation JSTARS in order to recommend approaches for solving their BMC2 needs. The goals of this work were to: 1) define and embrace a forward-looking battle management approach that removes boundaries from current operations, 2) determine the value in coupling traditionally separate BMC2 systems, and 3) improve future BMC2 delivered capabilities. The sprint identified several findings and made recommendations related to the processing and distribution of sensor data as well as other systemic issues associated with realizing a μ BMC2 capability.

3 How do I do DSEA&A?

There are many ways to do DSEA&A but there are some general steps to perform and an approximate order to those steps. Steps can overlap and be revisited as additional information is obtained or as change occurs over time.

Figure 2 shows the overall approach to DSEA&A. The need for a DSEA&A sprint is determined by a set of stakeholders¹² who together have a common interest in achieving some desired outcome(s) associated with the domain. The domain engineer works with these stakeholders to define the domain, the desired outcome(s), associated assessment criteria (measures of success), and the technical scope of the DSEA&A effort. The domain engineer then architects and analyzes the domain to identify options and assess them against the assessment criteria leading to various COAs for the stakeholders to consider. The stakeholders subsequently make decisions to: 1) do additional DSEA&A, 2) follow a selected COA to effect the desired outcome, or 3) otherwise end the DSEA&A effort.

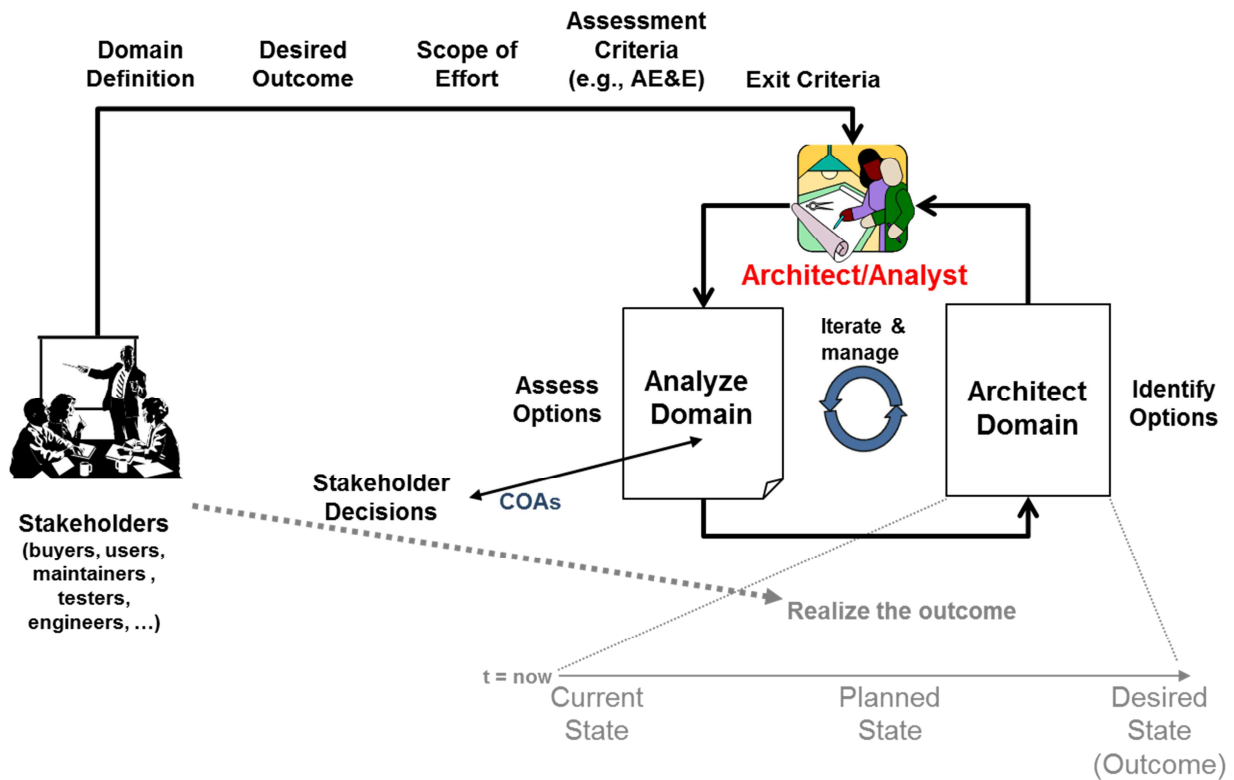


Figure 3 – Domain Systems Engineering, Architecture, & Analysis

¹² Not all stakeholders have an equal stake in the success of the DSEA&A effort. For example, there may be a small set of stakeholders who provide significant resources for the effort and who may be considered as “customers” of the effort. In some cases, there may be a single customer.

DSEA&A includes the following steps:

1. Setup the effort
2. Develop the Architecture/Model
3. Perform the Analysis
4. Identify and document COAs
5. Manage & evolve the effort

We will discuss each of these steps in turn, but some general orientation up front is useful. Step 1 defines and scopes the overall DSEA&A effort. Steps (2) and (3) are where the bulk of the heavy lifting occurs. Step (4) is the critical clean-up effort that transforms the heavy lifting into something actionable. Step (5) simply acknowledges that DSEA&A is iterative and continues until such time as someone in authority decides to stop.

3.1 Step 1 – Setup the Effort

It's critical to get off on the right foot, and this starts with establishing the sprint team, identifying the stakeholders, characterizing the domain, defining the right problem to address, identifying assessment and exit criteria, and scoping the DSEA&A activities. Note that these steps are not strictly sequential. In addition, they iterate – with feedback informing subsequent iterations. For example, the sprint team may evolve over time as the understanding of the domain evolves and the need for certain skills becomes evident. The sprint team elicits from the key stakeholders the kinds of decisions needed to achieve the outcome. The team typically documents the results of this step in a Terms of Reference (ToR) to be signed by key stakeholders. See Appendix F for a description of typical ToR contents.

Establish the Sprint Team: The sprint team will consist of appropriate personnel from (potentially) a variety of disciplines to include engineering, finance, program management, and contracting (among others). The team should include government, FFRDC, and contractor support personnel. Government advocacy and active participation is important. A single individual should be identified as the sprint leader. Train the team members as needed in:

1. The nature of the domain
2. The scope of the sprint
3. DSEA&A basics

Once the sprint is concluded, the sprint team might form the core of a more long-lived (but possibly part-time) domain focus group.

Identify the stakeholders: (This is done in concert with defining the domain.) A domain can have a wide range of stakeholders depending on the nature of the problem(s) being considered. As the precise problem being considered may not be known or well-understood early on, it is generally appropriate to cast a wide net initially and then scope down the list of stakeholders as matters become more concrete. Eventually, the domain engineer wants to focus on those key stakeholders with whom he/she plans to engage. Typical stakeholders include the domain authority, users/operators, administrators, maintainers, developers, planners, budget sources,

acquirers, testers, trainers, sustainers, researchers, etc. as well as any other decision-makers associated with the sprint. Eventually the domain engineer will engage with the stakeholders to identify the stakeholders' needs or equities relative to the domain. See Appendix G for a discussion of metrics related to stakeholder engagement.

As the problem gets defined and the DSEA&A effort gets scoped, the domain engineer should be thinking about specific stakeholder decisions needed to realize the outcome. This could include strategic investment decisions, specific programming decisions, contractor engineering decisions, etc. Be sure to understand the nature of such decisions and the role they play in realizing the outcome. Eventually the domain engineer will develop COAs and assessment criteria that allow him/her to determine the relative merits/drawbacks of each COA in an unbiased, consistent and defensible manner.¹³

Characterize the domain: As stated above, a specific domain is a partitioning of an overall problem space. It can be defined based on mission characteristics, technical characteristics, political characteristics, etc. While it may not be feasible to precisely define the domain, it is very useful to have at least a working characterization to ensure that the domain engineers focus their effort on relevant entities. Don't assume that such labels as 'C2,' 'ISR,' 'cyber,' and 'sensors' are precisely understood concepts. Provide additional modifiers and descriptors to add clarity. Provide definitions of key terms as needed. Identify parent and child domains where relevant. Consider the span of control of the decision maker.

Define the desired outcome: Develop a statement of the desired outcome (a desired change from the current state of the domain) based on an understanding of the domain, the associated stakeholders, and the stakeholders' needs/interests/equities (by performing a stakeholder analysis [4]).

When formulating the desired outcome:

- Consider the feasibility of achieving the outcome (either wholly or partially). Avoid over-reaching for "world hunger" types of outcomes but don't focus on trivial ones either. While guided by things like Vision statements, a good desired outcome should be more tangible (e.g., to make some specified progress in realizing a particular military capability).
- Look for outcomes that are domain-level in nature. Avoid outcomes that are broader ("enterprise" level) or narrower (e.g., specific to a given program).
- Identify the timeframe in which the outcome should be realized. Some decisions may impact current year funding, while others may impact long term budget planning. Ideally, you should be able to make some defined progress towards the outcome within a couple of years.
- The outcome should be owned by the key stakeholders. Engage with key stakeholders to get concurrence on the statement of the desired outcome.

¹³ Identification of COAs might be deferred to a follow-on activity based on the analytic results and available resources.

Remember that the understanding of the domain will likely evolve over time; however, it is important to converge on a “good enough” statement of the desired outcome early on to avoid pursuing dead ends wherever possible. The outcome, after all, drives the rest of the DSEA&A effort. It specifically leads to questions to be answered by the analysis.

Develop assessment criteria: As part of defining the outcome(s), develop an understanding of how progress towards achieving the outcome will be assessed. The assessment criteria are used to gauge how a particular solution rates in the broad categories of Affordability, Efficiency and Effectiveness. Each category should have a list of more specific criteria that make up the assessment. For example, Effectiveness might call out that some or all operational requirements are met or that there is no loss of mission effectiveness as defined by the existing capability currently in operation.

Identify exit criteria: The exit criteria are used to define what would constitute “as-planned” completion of the sprint effort. This could be, for example, any or all of the following:

- The outcome(s) has been achieved.
- Decisions needed to achieve the outcome(s) have been made.
- Sprint products/artifacts have been delivered and approved.
- A pre-specified level of effort limit has been reached.

Specific exit criteria should be tailored to the domain, the outcome(s), supporting products, and the set of stakeholders.

Scope the DSEA&A Activities: The problem/outcome statement leads to the identification of specific questions to be addressed by the DSEA&A effort, e.g.:

- “What is the needed capability?”
- “What are the current capability gaps?”
- “How many of what kinds of systems could provide the needed utility?”
- “Is the needed capability affordable?”
- “How should we engineer those systems (to best effect)?”
- “How should we deploy and use those systems (to best effect)?”
- “How well will some particular system configuration perform?”

DSEA&A emphasizes the use of appropriate engineering rigor. “Engineering rigor” implies the use of a deliberate and repeatable analytic methodology against a set of data (the model or architecture). “Appropriate” engineering rigor is that degree of rigor that provides “good enough” answers to the questions. Evolve the ToR as needed. Identify specific architecture and analysis tasks. Define the kind of data that is needed to support the stakeholder decisions. Identify relevant engineering artifacts (e.g., the domain architecture, analytic results). Decide what level of detail is needed to provide the appropriate rigor (in other words, right-size the architecture (breadth and depth) and the analysis (type, level of effort)). Identify specific progress metrics. Remember the old adage, “Better is the enemy of good enough.”

3.2 Step 2 – Develop the Architecture/Model

The domain architecture is a representation (model) of the salient aspects of the domain. (Hereafter, the term ‘architecture’ is used to also mean ‘model.’) The salient aspects are those that are needed to support the planned analysis that will in turn support the identified stakeholder decisions. The domain architecture should have only as much detail as is needed to support the analysis.

Of note, the domain architecture is not the sum of the relevant lower-level architectures but is rather an abstraction of them that highlights only those characteristics that are central to the DSEA&A effort. The architecture generally reflects those aspects of the domain that are pertinent to the use of the architecture (in this case, to support analysis related to the desired outcome). This could include various (and selected) DOTMLPF¹⁴ aspects.

The architecture generally represents multiple timeframes to include the ‘as-is,’ the ‘as-planned’ (to-be), and (potentially) multiple alternative ‘could-be’ states.¹⁵ (These alternatives generally line up with the COAs that get identified and assessed as a result of the analysis.) Optionally, it can include an ‘ultimately desired’ future state (a target). Each such “version” of the architecture should be relatively simple and oriented to the desired outcome(s). Different versions can be expressed by highlighting the (planned, proposed, potential) changes in the architecture over time (e.g., versions of systems, new systems, and interface mechanisms).

Use appropriate data mining of stakeholder needs, interviews, surveys, observations, etc. to collect and structure relevant architectural data (data about salient aspects of the domain). Use various modeling or architecture tools to store, process, and visualize that data. For DoD efforts, DoDAF [5] provides a framework for representing and visualizing architectural data. Use of DoDAF tools may be helpful, but the sprint team must determine the appropriate architecture artifacts to develop and how to develop them.

Evolve the architecture over time as insight is gained into the domain as a result of analysis and other investigations.

Be sure to have appropriate domain stakeholders validate the architecture.

3.3 Step 3 – Perform the Analysis

In DSEA&A, analysis is a deliberate effort to answer key questions in support of the decisions of the key stakeholders. The analysis leads to an improved understanding of the domain’s problem space and solution space. The analysis can also uncover additional questions related to newly discovered issues, risks, and opportunities while seeking to address earlier questions. A major goal of the analysis step is to converge on an enhanced understanding of the feasibility and utility of various alternatives for realizing the desired outcome.

To perform analysis:

¹⁴ Doctrine, Organization, Training, Materiel, Leadership and education, Personnel, and Facilities

¹⁵ This can be viewed as multiple versions of the domain architecture each representing a single timeframe or chosen alternative.

- 1) Review the assessment criteria
- 2) Assess (challenge/critique) alternative future domain states against those criteria
 - a) Identify issues, risks, and opportunities associated with those states
- 3) Document the analysis results

Define the basis, or “perspective,” of each analysis – generally oriented to the desired outcome and assessment criteria in some way. The perspective tends to shape the types of findings produced by the analysis. The perspective(s) include such things as AE&E, technology maturity, conformance to standards, and even schedule alignment.

There are many types of analytical approaches to include “back of the envelope” calculations, simulations, optimization approaches, prototyping, and heuristic algorithms. There are many variations in each of these classes (e.g., simple computation, discrete-event simulation, linear programming, and genetic algorithms). Some analyses seek to find optimal solutions while others seek feasible (good enough) solutions. Some analyses are static while others look at various conditions over time.

Once completed, document the findings and associated recommendations to support subsequent stakeholder decision-making. Appendix E lists some typical artifacts for documenting sprint results.

Some things to consider when performing the analysis include:

- Understanding dependencies and other relationships
- Identifying appropriate scenarios, initial conditions, etc.
- Understanding the impacts of operational, system, and technological change

It is important to understand the pedigree of the analytical results – how much confidence should one ascribe to those results. Document the assumptions and constraints in the model (as it is instantiated) as well as the limitations of the chosen analytical approach.

3.4 Step 4 – Identify and Document COAs

Analytical results need to be reviewed, interpreted, and then transformed into practical actions. This is where “the rubber meets the road.” As part of the analysis, the domain engineer identifies and assesses various alternative Courses of Action (COAs) to support decision-making related to achieving the desired outcomes. A COA is a sequence of steps for effecting a change in the state of the domain – or, stated another way, for achieving a desired outcome. COAs are generally judged on the basis of cost, benefit (e.g., degree to which they achieve the outcome), and overall risk, but there may be other specific factors relevant to the domain.

COAs often cross the full spectrum of DOTMLPF (Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities). All functions should be considered in the analysis for completeness. The amount of detail in a COA should be commensurate with the degree of rigor

required for the analysis and the level at which the decision needs to be made. Some examples of COAs to be investigated are:

- Revise a business process
- Improve the training of personnel
- Accelerate the fielding of new or updated materiel
- Modernize a (set of) system(s) in a specified way to improve an operational capability
- Implement a new system or system of systems architecture
- Invest in a particular technology
- Engineer systems to conform to some technical reference architecture
- Leverage a specific solution across multiple situations
- Do more DSEA&A (but be careful to avoid “analysis paralysis”)

Typical decisions resulting from the identification of COAs include:

- Pursue a specified COA as defined
- Request additional work to refine a specified COA
- Reject all COAs as presented (and either restart or terminate efforts to identify an acceptable COA)

Figure 4 presents an example of a COA presentation, including factors and “pros” and “cons” to be weighed by the decision maker:

COA 1: Complete Block 10.X Currently Contracted Work

- COA Description: Complete work on currently contracted DO/TDs and deliver “As is”
 - Re-use Block 10.X hardware, software licenses, and GFE items on fielded baseline
 - Install and integrate portion of developed s/w for workflow

	PRO's	CON's
TIME		<ul style="list-style-type: none"> - Schedule replanning to be done - Delays IOC at first site to 1QFY13
COST	<ul style="list-style-type: none"> - No contract termination penalties (~ \$ 70M) 	<ul style="list-style-type: none"> - Continues expenditure of Block 10.X funds for existing DO/TDs and risk of needing more funding later to complete (~ \$232M FYDP)
CAPABILITY	<ul style="list-style-type: none"> - Adds Enhanced Workflow Management Capability - Adds 20 additional workstations and server hardware per site - Adds 8x storage and throughput capacity beyond current baseline 	<ul style="list-style-type: none"> - Fielded baseline meets current mission need but has risk associated with accommodating new interfaces - 10.X baseline has outdated hardware in need of refresh before operating

Figure 4 – COA Example

3.5 Step 5 – Manage and Evolve the Effort

In this “clean-up” step, the key stakeholders, in conjunction with the sprint team, look introspectively at the DSEA&A effort and decide on a way forward. They review the status of the effort against the previously defined exit criteria. Doing more analysis may provide critical information – or it may be overkill. Identify changes that may invalidate a portion of the work done to date.

Maintain configuration control of any DSEA&A artifacts¹⁶ created to date and update the schedule of future DSEA&A activities (if any). Update and document accumulated lessons learned at appropriate points during sprint execution.

¹⁶ See Appendix E for a list of typical DSEA&A artifacts.

4 Summary

Domain Systems Engineering Architecting & Analysis (DSEA&A) (aka “Domain Analytics”) is an approach for achieving desired outcome(s) that pertain to some domain of interest; a domain being a bounded part of the problem space having an identifiable controlling individual or group of individuals authorized to make decisions. DSEA&A builds on traditional systems engineering and architecture and analysis methodologies. It is a viable means for addressing issues, risks and opportunities that cut across multiple programs within or across PEO boundaries. A key feature of DSEA&A is the proactive engagement with appropriate stakeholders in the domain to ensure that appropriate analysis forms the basis of investment and engineering decisions.

DSEA&A is not a single prescriptive method of performing analysis. It is a flexible framework accommodating many kinds of analysis and is often amenable to execution in an agile fashion via “sprints”.

Appendix A References

- [1] CJCSI 3170.01H, Joint Capabilities Integration and Development System (JCIDS), 10 January 2012
<https://acc.dau.mil/CommunityBrowser.aspx?id=267681> (registration required)
- [2] CJCSI 8501.01A, Chairman of the Joint Chiefs of Staff, Combatant Commanders, and Joint Staff Participation in the Planning, Programming, Budgeting, and Execution System, 3 Dec 2004 (Current as of Feb 2008), www.dtic.mil/cjcs_directives/cdata/unlimit/8501_01.pdf
- [3] DoDI 5000.02, Operation of the Defense Acquisition System, 8 December 2008
<http://www.dtic.mil/whs/directives/corres/pdf/500002p.pdf>
- [4] Stakeholder Analysis Guidelines, Kammi Schmeer,
<http://www.who.int/workforcealliance/knowledge/toolkit/33.pdf>
- [5] DoD Architecture Framework (DoDAF), <http://dodcio.defense.gov/sites/dodaf20/>
- [6] Model-Based Systems Engineering (INCOSE), <http://mbse.gfse.de/>
- [7] Manifesto for Agile Software Development, <http://agilemanifesto.org/>
- [8] Outcome-Directed Thinking: Questions that Turn Things Around,
www.terry.uga.edu/~bostrom/Outmodel.doc
- [9] DoD Systems Engineering Guide for Systems of Systems, V1.0, Aug 2008,
<http://www.acq.osd.mil/se/docs/SE-Guide-for-SoS.pdf>
- [10] Merriam-Webster definition of “domain”, <http://www.merriam-webster.com/dictionary/domain>

Appendix B Bibliography

INTRODUCTION TO MODELING AND SIMULATION, Anu Maria, State University of New York at Binghamton, Department of Systems Science and Industrial Engineering, Binghamton, NY 13902-6000, U.S.A., Proceedings of the 1997 Winter Simulation Conference, ed. S. Andradóttir, K. J. Healy, D. H. Withers, and B. L. Nelson

“Theater C2 Sprint 1 Affordability, Effectiveness, and Efficiency (AE&E) Analysis and Process,” Modeen, R.A., Ricci, L.R., MITRE Technical Report (MTR) 120164, May 2012

Appendix C Acronyms

AE&E	Affordability, Efficiency, and Effectiveness
C2	Command and Control
CFLI	Core Function Lead Integrator
CFMP	Core Function Master Plan
COA	Course of Action
CONOPS	Concept of Operations
DAS	Defense Acquisition System
DoD	Department of Defense
DoDAF	Department of Defense Architecture Framework
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and education, Personnel, and Facilities
DSEA&A	Domain Systems Engineering, Architecting, and Analysis
ISR	Intelligence, Surveillance, and Reconnaissance
JCIDS	Joint Capabilities Integration and Development System
PfM	Portfolio Management
PPBE	Planning, Programming, Budgeting, and Execution
POM	Program Objective Memorandum
SE	Systems Engineer or Systems Engineering
SoS	System of Systems

Appendix D Affordability, Efficiency, and Effectiveness

“Affordability, Efficiency, and Effectiveness” refer to three interrelated concepts that are informally defined as follows:

- Affordability – ability to fund desired investments
- Effectiveness – the bang; ability to achieve an organization’s mission
- Efficiency – measure of the “Bang for the Buck” or “unit benefit per dollar”

Generally, the overall goal is to realize efficiency without sacrificing effectiveness unnecessarily while staying within the constraints of affordability. Stated another way, the total cost of a solution should not exceed some specified budget; the effectiveness (utility, benefit) of a solution should not be below some minimum; and the ratio of effectiveness to cost should be at a maximum within the previous two constraints. This avoids low-cost, but also low-effectiveness solutions as well as high-cost solutions that don’t deliver commensurate effectiveness and may exceed affordability constraints.

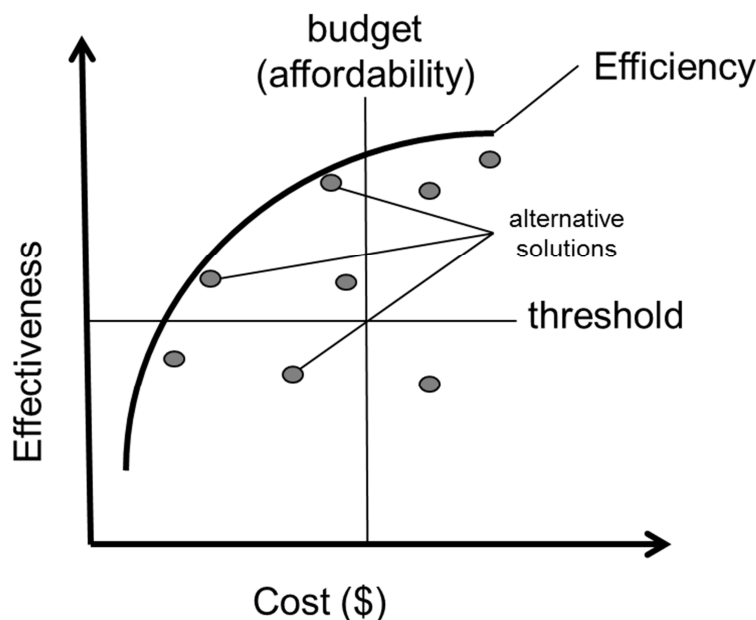


Figure 5 – Affordability, Efficiency, and Effectiveness

There are many ways to measure cost and effectiveness. Note specifically that effectiveness can be a combination of many ‘-ilities’ to include functionality, performance, reliability, availability, security, etc. Measures of Effectiveness (MOEs) are generally capability-specific. They reflect stakeholder values.

Appendix E Potential DSEA&A Artifacts

The following shows some potential DSEA&A artifacts. The primary artifacts are the domain architecture and the results of the analysis. This is not intended to be a complete list.

- Sprint Terms of Reference
- Sprint Plan
- Domain/Sub-Domain (reference) Architecture Baseline
 - Perspective Overlays - Questioning/Challenging
- Affordability, Effectiveness & Efficiencies (AE&E)
 - Opportunities Identification
 - Justification Analyses
 - Performance - Cost Drivers Sensitivity Analysis
 - Requirements Analysis and Rationalization
 - Certification and Accreditation (C&A) Implications
 - Vulnerability Assessments (MA, Robustness-Resiliency-Adaptability, Composeability, etc.)
 - System of System Performance Models
 - Integration and Interoperability (I&I) Constraints/'Desirements'
 - Quick Reaction (early) Capability (QRC) Potential
- CFMP Futures Recommendations & CFLI Support Obligations/Proposals
- Reference Design/Architecture (proposed direction/details)
- Capability Roadmaps (dependencies and required efforts synchronization)
- Risk Assessments, Engineering Watchlists
- Interface Definitions and Constraints/Opportunities
- Relevant Technology Assessments
 - Transition Opportunities (Labs, Industry, ...)
 - Relevant COTS/MIL Developments
 - Critical Technology Elements (CTEs) Identification
 - Program Protection/Anti-Tamper considerations
 - Technology Readiness (level) Assessments (TRAs)
- Standards Determination (Open, COTS, Mil-unique, etc.)
- Independent Technical Assessments (ITA)
- Experimentation/Prototyping/M&S Recommendations
- Supportability ('ilities') Implications Assessment

Appendix F DSEA&A Sprint Terms of Reference Typical Contents

- General Background Information
- Motivation for Conducting the Sprint
- Sprint Scope and Goals
- Sprint Governance Structure
- Stakeholder/Participant Roles and Responsibilities
- Sprint Method of Operation (e.g., Ground rules, Sprint Process, Tools, Review, Reporting)
- Relevant Policies, Procedures and Guidelines
- Sprint Products
- Sprint Schedule
- Resources Required (at all levels and from all stakeholders)
- Sensitivity of Information

Appendix G Stakeholder Engagement Metrics

1. Sprint has a Government customer¹⁷

- Threshold: Sprint scope (sprint outcome, context, exit criteria, stakeholders, and sprint approach/duration) is documented and approved by appropriate stakeholders

2. Gov't provides an Engineering focal point

- Threshold: A Government Engineering focal point is designated and is available (at least weekly) to guide effort
- Objective: Government Engineering focal point is proactively engaged throughout the Sprint and enables stakeholder involvement, including at least one vector-check with key stakeholders during sprint and periodic management updates

3. Stakeholders are appropriately involved in Sprint

- Threshold: Stakeholder group includes at least one (Government) MAJCOM/User representative and all (planned) stakeholders (or designated representatives) participate in a Sprint kickoff, providing opportunity for feedback on sprint execution approach
- Objective: At least the “key” stakeholders (per approved sprint scope) participate continuously throughout sprint, enabling team access to the right guidance, information and people at the right times to efficiently execute the sprint and develop planned products

4. Stakeholders are provided the sprint results

- Threshold: All stakeholders receive a sprint readout package
- Objective: All stakeholders are briefed and provide feedback on sprint results and implications

5. Sprint results are leveraged/applied

- Threshold: By key stakeholders
- Objective: (Also) by other relevant stakeholders

¹⁷ A customer is a type of key stakeholder who provides resources for the sprint.