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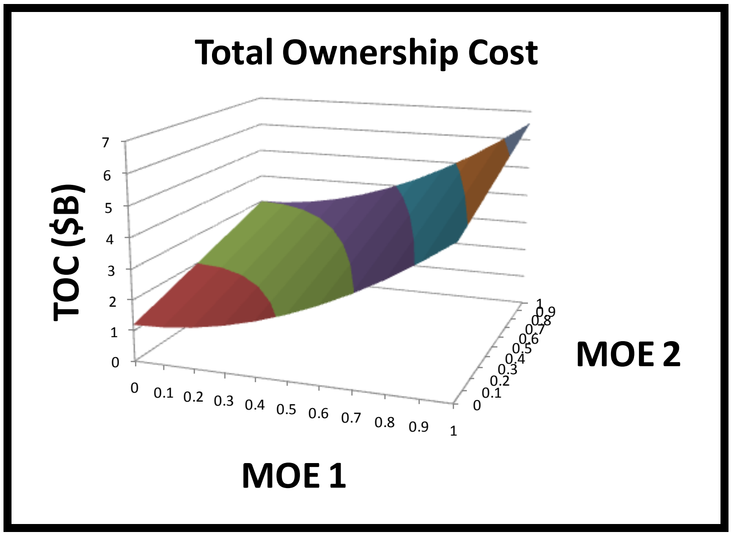
GUIDE FOR CONDUCTING TECHNICAL STUDIES



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GUIDE FOR CONDUCTING TECHNICAL STUDIES

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14. ABSTRACT

Technical studies provide insight to leaders that help them make decisions. These decisions can be of small magnitude, or could impact the expenditure of billions of dollars and the lives of many individuals. Following repeatable, documented engineering processes to produce reliable and timely technical studies can significantly enhance the quality of these decisions. The guide was written for NAVSEA and Warfare Center Engineers and their supporting contractors in planning and executing technical studies. This guide may also prove useful to other organizations since the issues and best practices are not unique to NAVSEA.

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LIST OF ACRONYMS

ANSI	American National Standards Institute
AOA	Analysis of Alternatives
DOD	Department of Defense
DSM	Design Structure Matrix
DTIC	Defense Technical Information Center
EVMS	Earned Value Management System
GAO	Government Accountability Office
ISO	International Organisation for Standardisation
JCC(X)	Joint Command and Control Capability
MSC	Military Sealift Command
NAVSEA	Naval Sea Systems Command
NIST	National Institute of Standards and Technology
OP-TEMPO	Operational Tempo
ROM	Rough Order of Magnitude
SBD	Set Based Design
VV&A	Verification, Validation, and Accreditation

1. INTRODUCTION

Technical studies provide insight to leaders that help them make decisions. These decisions can be of small magnitude, or could impact the expenditure of billions of dollars and the lives of many individuals. Following repeatable, documented engineering processes to produce reliable and timely technical studies can significantly enhance the quality of these decisions. This guide captures the lessons learned and best practices from studies conducted in the Naval Sea Systems Command (NAVSEA) since 2004. Much information from this guide was derived from the Ship Design Manager Manual (NAVSEA 2009), a draft Ship Concept Design Handbook (NAVSEA 2006) and a predecessor SEA 05D memorandum on "Ship Concept Study Process" (NAVSEA 2005). This guide is consistent with the SEA 05D memorandum on "Surface Ship Concept Study Policy" (NAVSEA 2010). Mike Buckley provided the section on Decision Oriented Systems Engineering.

The guide was written for NAVSEA and Warfare Center Engineers and their supporting contractors in planning and executing technical studies. This guide may also prove useful to other organizations since the issues and best practices are not unique to NAVSEA.

In its review of the Mobility Capabilities and Requirements Study 2016, The Government Accountability Office (GAO 2010) provides a good list of "Generally Accepted Research Standards" in table 1 of the document. While this guide is consistent with these standards, study leaders should consider reviewing the table.

The general technical study process described in this document is depicted in Figure 1. While this process is generally applicable to technical studies ranging from a few days in duration to a few years in duration, the level of effort in each activity may differ significantly. While tailoring of the activities within each "box" of Figure 1 is appropriate, careful thought should be given prior to eliminating any "box."

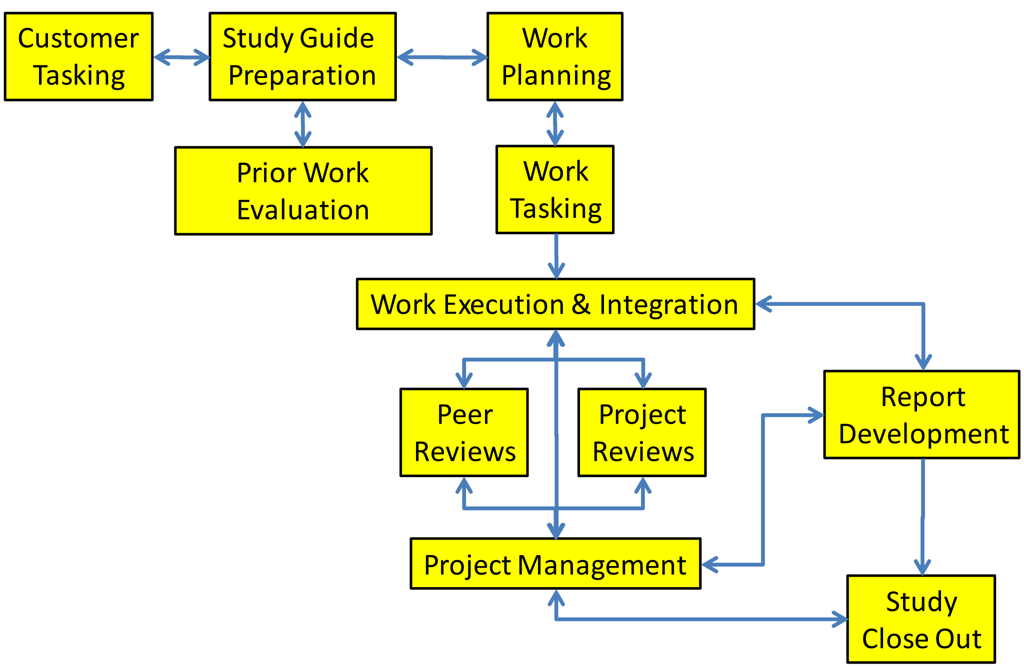

Figure 1: Technical Study Process

Figure 2 shows an alternate view of the technical study process. A Design Structure Matrix (DSM) shows the dependency of the different activities upon each other. In this rendition of the DSM, a 1 in a cell indicates that the activity corresponding to that row depends on the activity corresponding to the column. The DSM clearly shows that the Technical Study Process can be thought of in terms of two stages: Work Definition (green), and Work Execution (blue).

Customer Tasking		1								
	Prior Work Eval	1								
1	1	Study Guide Prep	1							
		1	Work Planning	1						
			1	Work Tasking						
				1	Work Execution & Integration	1	1	1	1	
					1	Peer Reviews		1		
					1		Project Reviews	1		
					1	1	1	Project Management	1	1
					1			1	Report Development	
								1	1	Study Closeout

Work Definition   Work Execution

Figure 2: Design Structure Matrix (DSM) view of Technical Study Process

The organization of this document is based on Figure 1 and Figure 2. Emphasis is placed on the Work Definition activities because experience has shown that good planning is critical to the successful execution of a study. Furthermore, the details of the Work Execution phase are often study dependent and defined in the Study Guide which is produced in the Work Definition phase.

NOTE: This document refers frequently to "serialized" documents. A "serialized" document is dated, has a title, has a unique identifier (typically a serial number) associated with it, is approved by the organization as a final version of the document, and is entered into the organization's document / correspondence management system.

2. WORK DEFINITION

2.1 Customer Tasking

Customer tasking can come in many different ways. Large, complex studies typically are initiated by letter or memorandum describing the study tasking and the requesting organization point of contact. Generally, funding for these studies is specified in separate funding documents. Less complex studies may be requested by email, hand written memo, or even orally. Experience has shown however, that normally the originator of the tasking is not experienced in specifying exactly what is needed. Often the tasking is too detailed in certain areas and lacks critical detail in other areas. Consequently, before expending too many resources on a problem that is not well defined, it is best to spend time to properly define the problem in a study guide that is understandable to the customer, study stakeholders and the Study Team.

2.2 Study Guide Preparation

Before charging off to execute the study, the study leader should take time to ensure that he/she is on the same wavelength with the study stakeholders and customer. It is frustrating to discover misunderstandings after completing lots of fruitless work. Everyone needs to fully understand who the customer is, what questions he/she wants answered, when an answer is expected, and what resources are available. Developing the study guide will lead to the alignment of the study to customer expectations. At a minimum, the study guide should:

1. Identify the customer, tasking method, tasking date, what specific information the customer wants and what specific question the customer wants answered from the study.
2. Identify the general approach for conducting the study. State the level of effort to provide the requested information, the degree of uncertainty in the requested information, and how long the study will take.
3. List key study assumptions that would require re-scoping of the study if they were changed.
4. List design and analysis tools (including version identification) that are planned for use as well as a high level Verification, Validation, and Accreditation (VV&A) assessment of these tools.
5. Provide a high level schedule.
6. List funding or other resources that your customer and others will provide.
7. List major deliverables and when they will be completed. Where necessary, provide some level of detail as to the contents of the deliverables.
8. Identify the individual who will lead the study.

One cannot overemphasize the importance of translating the customer tasking into one or a few specific questions that if answered accurately, will satisfy the customer. The advantages of doing so include:

a. Work can be planned to focus specifically on answering the questions. Any proposed tasks that cannot be traced to answering the specific questions can generally be cut.

b. The study will usually take less time and be cheaper because unneeded work is not accomplished. Speed in conducting a study improves relevance -- if quality does not suffer. If a study takes too long to produce results, many associated decisions will already have been made. Good results, fast, provide great value to the customer. Providing the correct answer after the associated decision has been made has far less value.

c. The ability to differentiate in-scope and new-scope work is greatly enhanced. If proposed additional work does not contribute to answering the questions, then it is new-scope and treated as either a new study or a formal change to the current study.

For a short, simple study that you are conducting alone, the study guide should take no more than a few hours to prepare. A study guide for a long duration study involving a dozen or more individuals in several different organizations however, might require several weeks because it takes time to assemble a design team and to reach consensus on how to approach the problem. Everyone on your team should have access to the study guide, as should the stakeholders. It should be a living document throughout the course of your study, because you will probably need to revise your assumptions and adjust your schedule as you gain knowledge. Make sure that everyone on the team is aware of study guide changes through serialized revisions.

Study guides for moderate or long duration studies should incorporate a signature page to include the study leader, customer, and key stakeholders.

Occasionally, it may be difficult to achieve consensus among the study stakeholders and the customer on the assumptions or some other element of the study guide. In these cases, the study leader has several options:

a. The study leader can recognize the impasse in the study guide, and provide a means for resolving the impasse within the context of the study. For example, the study could incorporate an experiment to verify a contested assumption.

b. If there are only a few relatively minor issues that are holding up the issuance of the study guide, then the study leader may elect to continue on with Work Definition and Work Execution without an "approved" study guide; recognizing that a risk for rework exists. In general, there should be agreement on more than about 80% of the study guide content before proceeding on risk.

c. If there are significant issues holding up the study guide, these issues should be resolved by invoking the organization's processes for resolving technical issues. Work should only be conducted to the extent that the results of the work will resolve the issues.

Studies can be quite varied, but there are common elements among successful planning efforts. Here are some tried and true guidelines.

<u>Keep the objective in mind</u>. It is easy when planning or conducting a study to get sidetracked. We all tend to gravitate towards technical areas that we are more comfortable with or are

more interested in. Make sure focus stays on the right things. For every step of the plan, ask yourself, "Will this contribute towards answering my customer's questions?" And when you have finished your draft plan, ask, "Will these steps lead to the answers I need, or have I missed something?"

<u>Understand what pieces are missing</u>. Every study is a quest for information. Some of it will be on hand, some you can get with a little research, and some will take engineering to find. A key to managing study costs and schedules is to take advantage of previous work so resources are not wasted in discovering the same thing over and over. If your study needs new research or tools, it is best to figure that out early since either can take a lot of time and money to complete.

<u>Dig to the right depth</u>. One of the more challenging aspects of study planning is deciding how deeply to investigate each technical area. Detail costs time and money, but insufficient precision can cast doubts on the study's accuracy. A good way to address this conundrum is to work backwards from the technical areas that your final report will cover, and assess how far you are deviating from conventional practice or current technology. For example, if the maximum weight for a system planned for integration into a ship is well within the remaining service life margin of the ship, then a detailed weight estimate is likely not needed. However, if the system weight could exceed the remaining service life allowance, then more detailed analysis is required to better estimate the system weight.

<u>Parse the study into logical chunks</u>. The way to make headway in a complex study is to break it into manageable pieces. Each activity should have definite inputs, objectives and products.

<u>Highlight task relationships</u>. Managing a study team is largely about making sure that the right data flows where and when it is needed. You must understand how each of the activities impacts the others, and contributes to the overall objectives. The simplest method for clarifying task relationships is a flow chart. Another method is the Design Structure Matrix. Large studies will benefit from program management tools such as Microsoft Project or PLEXUS.

<u>Be clear about who will do what</u>. Each activity must have a leader who understands what product is expected, what resources are available, and when the activity is to be completed. The study leader might lead all activities for simple short duration studies, or just selected critical path ones for larger efforts.

<u>Budget plenty of time for documentation</u>. Report writing usually takes longer than expected, and the process often brings to light issues that need further attention. A best practice is to start the documents as early as possible in the Work Execution phase. For large studies, an outline of the reports should be developed as part of the Work Definition phase. Be warned that the review of documents by stakeholders can take longer than actually writing the document, so ensure you plan a sufficient time for document review.

2.3 Prior Work Evaluation

After making sure that you understand the problem, the next step is to see if it has already been solved. The fastest way to do this is to ask other engineers within your organization. In conducting a literature search, other sources of historical study information are your organization's document management system, the internet, libraries, and the Defense Technical Information Center (DTIC). Another term associated with this activity is "Market Research." Information on how to conduct Market Research can be found in DOD 1997. Customers will generally be delighted if you quickly (and inexpensively) provide results of a previous study that answers their questions directly. Even if your specific study question hasn't been addressed in a previous study, you will almost certainly find useful background data, similar studies for comparison, and helpful examples of study methodology.

2.4 Work Planning

2.4.1 Activity Modeling, Process Modeling, and Design Structure Matrices

An important part of planning a study of even moderate complexity is modeling the study process including the activities comprising the study. In the example shown in Figure 3, study activities are represented by rectangles, decisions by diamonds, and the flow of information between study activities by lines. To ensure the process is well integrated, particular attention is needed to describe the information expressed by the lines. The information produced by the source activity must be compatible and of the requisite quality required by the receiving activity. For more information on flowcharting, see ANSI X3.6-1970 or ISO 5807:1985.

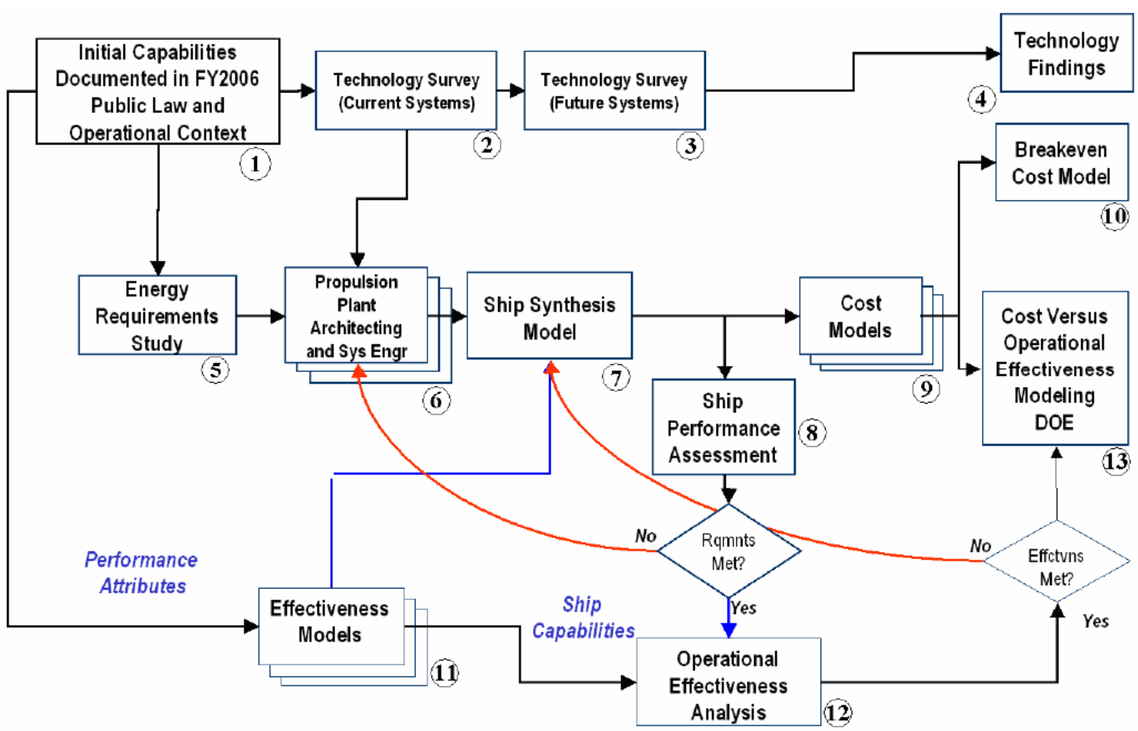

Figure 3: Example of a Study Process Model (Webster et al. 2007)

There are many ways to model a study activity for integration into a process model. A modeling technique that has proven useful over time is based on the IDEF0 definition of a function. As shown in Figure 4, an activity interacts with external activities via Inputs, Outputs, Controls, and Mechanisms. Inputs are those data elements needed to perform the activity. Outputs are those data elements that are produced by the activity. Controls impact the manner in which the activity is performed, and Mechanisms are the resources needed to perform the activity. For further information on IDEF0, see NIST (1993).

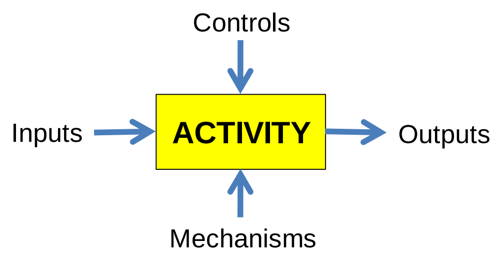

Figure 4: IDEF0 Activity Model

Within a process model, an activity's boundaries should be chosen such that the activity is accomplished by a single organization using a defined process and have well defined artifacts (such as reports, data files, forms, test articles, etc.) as inputs and outputs.

Figure 5 presents an alternate way to present a process model. In this Design Structure Matrix (DSM) representation, each activity is represented by a row. Its corresponding column represents "Outputs" the activity produces. Dots in the off-diagonal represent "Inputs" needed by the activity. These "Inputs" are provided by other activities as "Outputs". If the activities are ordered chronologically with the first activity on top, then any dot above the diagonal represents a feedback loop – "Inputs" are needed before they are created. This input data can either be assumed, or the results of a previous iteration can be used. These "above the diagonal" points define clusters of activities that are tightly coupled. Consideration should be given to redesigning the process to eliminate the clusters, co-locating the personnel accomplishing these activities, and integrating design and analysis tools to speed the execution of the feedback loop.

The DSM also can highlight activities that can be accomplished in parallel because the two activities do not depend on each other.

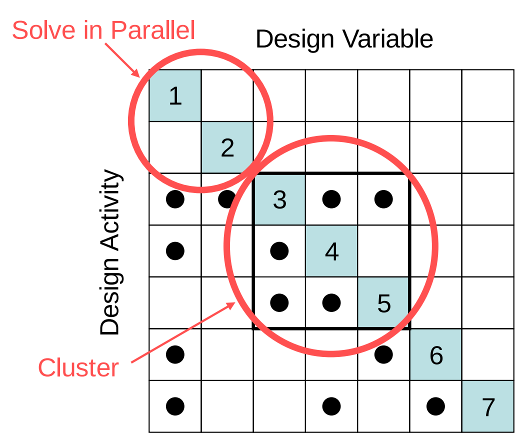

Figure 5: Example of a Design Structure Matrix (DSM) for a Design Study

For additional information on using DSM, see Doerry (2009), Browning (2001), Browning (2002), or the tutorials located on http://dsmweb.org.

2.4.2 Study Cost and Schedule Estimation

Relatively few studies are conducted entirely with in-house resources. Many times support contractors or Warfare Center / Navy Research Laboratory personnel are employed to provide capability that is not resident in-house or to provide additional capacity. The process model is a good tool to estimate the time and amount of labor required to complete the study. Some considerations in developing cost and schedule estimates include:

- The possibility of employing study participants part-time if constant workforce loading is not achievable. While costs can be reduced by using an engineer part time, schedule delays can occur because of schedule conflicts among multiple projects.

- The fully burdened cost, not the salary, of a contractor or Warfare Center / Navy Research Laboratory employee must be used in calculating costs. Additional funding for travel, equipment, and supplies may also be needed.

- The anticipated number of iterations required to complete the study. The DSM will identify where iterations are needed, but without additional information, does not provide insight as to the rate of convergence or the number of iterations needed.

- The anticipated involvement of stakeholders. If stakeholders are not willing to engage early in the process, considerable contingency funds / management reserve may be needed to develop unplanned information needed to satisfy the stakeholder.

- If the study requires resources that are limited in availability, the total study time, and therefore the costs can increase as activities wait for missing data, or proceed at risk with less reliable data.

- If new tools or methods are employed in the study, anticipate some rework as well as additional time for personnel to learn the new tool or method.

- Do not under-estimate the cost and schedule impact of coordination meetings, project reviews, and peer reviews. These meetings and reviews in addition to other management functions are essential to producing a quality product, but many times do not appear in the process model.

- Consider the impact of holidays and vacations on schedule. In developing the schedule, consider assuming no work accomplishment in any week with a holiday, and assuming 2 weeks unavailable during the summer.

- Do not under-estimate the time needed for the contracting process and tasking of Naval Warfare Centers / Navy Research Laboratories. The schedule must account for the estimated date when different participants are able to join the study team.

2.4.3 Study Techniques

2.4.3.1 Design Space Exploration & Design of Experiments

In many studies, the design space under consideration is a function of multiple interacting variables. In the Analysis of Alternatives (AOA) for the Joint Command and Control Capability conducted in 2000-2001, the four major drivers were staff size, survivability, MSC vs. Navy Manning, and ship speed. For this study, these four independent variables were fully explored with 24 point designs (Figure 6). The advantages of using a design space as compared to conducting trade-studies off of a baseline concept are:

- The impact of an independent variable on a dependent variable can be averaged over the full design space, not just the two point designs used in the trade-study. By averaging over the entire design space, the variance of the estimate can be reduced -- one produces better results.

- For some studies, a baseline concept does not naturally exist -- or there is considerable disagreement among the stakeholders as to which concept should be the baseline. A design space study doesn't need a baseline concept, so arguments among stakeholders to establish one are eliminated. However, one must ensure the design space encompasses the regions of interest of all stakeholders.

- Regions of local and global optimums can be better identified. In some cases, very different sets of independent variable values can produce nearly identical dependent variable values. A simple trade-study approach would likely not identify this phenomenon.

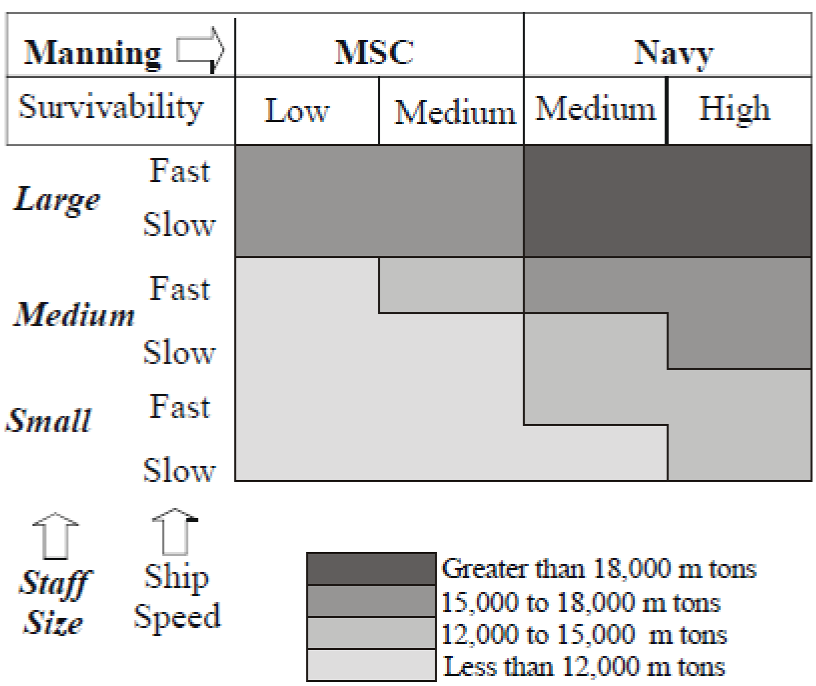

Figure 6: Example of Design Space Study results (Doerry and Sims 2002)

If the number of important variables is more than a few, consideration should be given to using statistical analysis tools such as JMP. Figure 7 and Figure 8 show representative results from JMP. These software tools also enable one to use Design of Experiments techniques which enable effective sampling of the design space with fewer points than the full sampling employed in the JCC(X) AOA. These alternate techniques include Box-Behnken, Central Composite (Box-Wilson) and Taguchi methods (Whitcomb 2004).

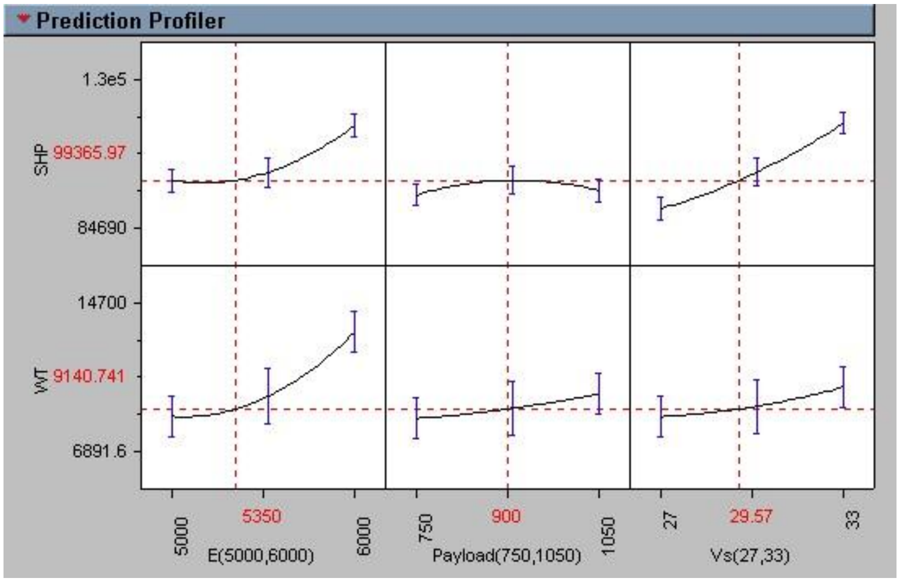

Figure 7: JMP Prediction Profiler (Whitcomb 2004)

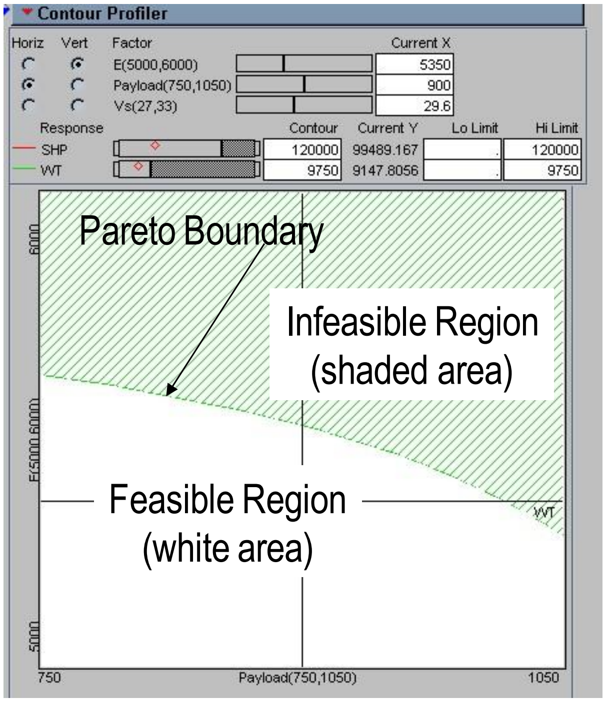

Figure 8: JMP Contour Profiler (Whitcomb 2004)

2.4.3.2 Set Based Design approaches

Set Based Design (SBD) is a method where the solution is obtained by systematically eliminating combinations of independent variables which can be shown through study activities to NOT be the solution. As more and more of the solution space is eliminated by rigorous analysis, the solution becomes apparent. By systematically demonstrating what is not the solution, study stakeholder buy-in is generally easier to obtain. (You can diminish and address the endless "Did you consider this?" questions)

The first step in SBD is defining feasible regions of the solution space. This can be either a feasible variable range, such as length or speed, or discrete states of design such as electric drive or traditional gear driven vessel. Once the feasible regions are established, different specialties explore tradeoffs by designing/evaluating multiple alternatives within their domain. As the engineers explore the design alternatives they communicate the sets of possibilities back to the other team members and the Study Integrators. (Singer et al. 2009)

As depicted in Figure 9, the three principle concepts to implement Set Based Design (SBD) are (1) consider a large number of alternatives by understanding the solution space / design space, (2) allow specialists to consider a solution from their own perspective, and (3) use the intersection between individual sets to optimize a global solution and establish feasibility before commitment. (Bernstein 1998). The optimization process can consider physical performance of a solution, as well as other attributes such as producibility and acquisition complexity.

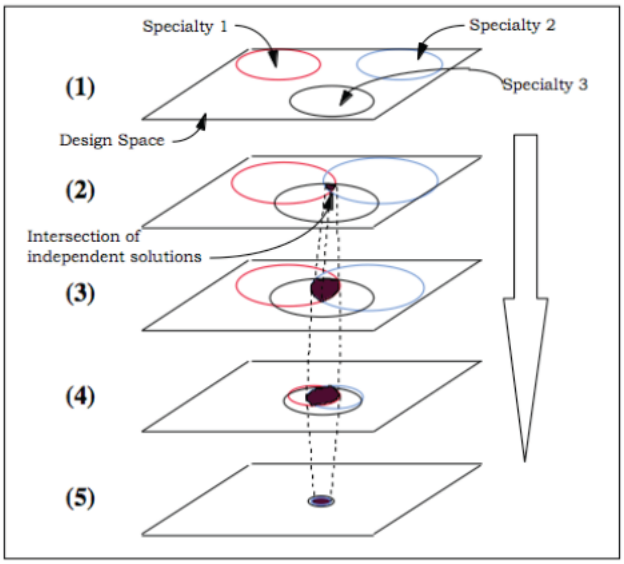

Figure 9: Set Based Design (Bernstein 1998)

As each group of specialists produces domain solutions within their area of responsibility, their solutions are integrated into the larger context. To “integrate by intersection” the Study Integrators lead the study team in identifying intersections of feasible sets among the groups. This requires prior agreement of the minimum and maximum bounds of each set. Specialists cannot extend beyond the bounds unless no other options remain.

The ultimate goal of the integration process is a smaller set of unified global solutions created by integrating the sets of domain solutions completed by different functional groups. The integration process is facilitated by conceptual robustness. Conceptual robustness is achieved when results concerning one aspect of a study remain valid in the face of subsequent results in other aspects of the study. (Singer et al. 2009)

2.4.3.3 Decision Oriented Systems Engineering

One very efficient way of looking at a desired study is to consider the study in the light of the questions and decisions one intends to address in conducting the study. What is the ultimate question is being asked and what questions will have to be asked to resolve the ultimate question? Such is the decision-oriented approach to defining and executing technical studies. If the intended study is not a simple "redo" with tweaks of an earlier, similar study, the decision-oriented approach can provide a path to a truly innovative approach.

One decision-oriented method known as Decision-Oriented Systems Engineering (DOSE) involves looking at the problem domain as an evolution of knowledge punctuated by key decisions. The premise behind the DOSE method is that any problem (in this case, an anticipated study) is best viewed as a network of key decisions supported by quality information and human judgment that must be successfully navigated for satisfactory resolution. This evolution of knowledge is captured as a knowledge map based on the conventions depicted in Figure 10.

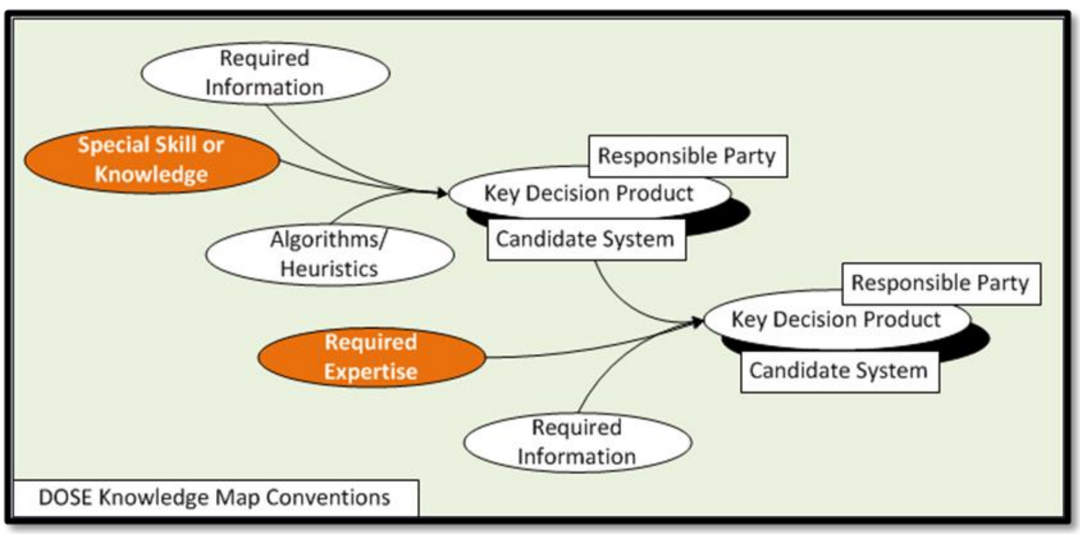

Figure 10 Conventions for a Completed DOSE Knowledge Map

The decisions are key cognitive decisions (decisions involving human judgment or some reasonable facsimile thereof), and are described as decisions made, not as enumerated sets of future choices. This abstraction allows for decisions to be described as classes of decisions, simplifying the required complexity of the decision network and resulting knowledge map. See

Figure 11 for an example knowledge map depicting a simplified and notional implementation of Set Based Design.

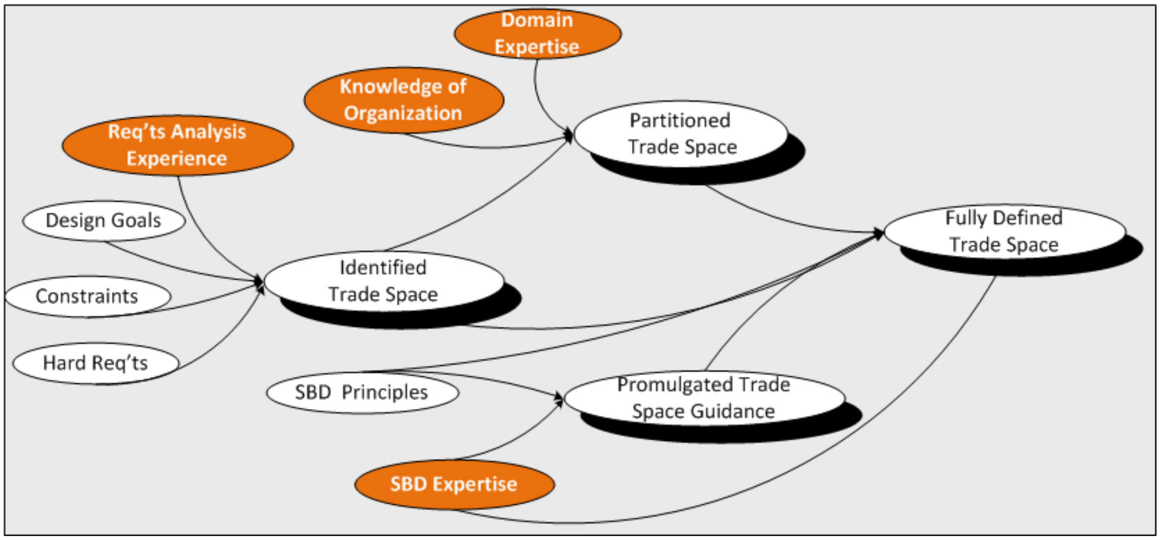

Figure 11 Notional DOSE Knowledge Map Depicting the Trade Space Definition Element of a Set-Based Design Implementation.

The details of executing the DOSE method are described in U.S. Patent #7493298 and summarized in Buckley & Stammnitz, (2004), and in Buckley & Womersley, (2007). The DOSE method begins with a partitioning exercise and derived objective statements that hint (at least) at what will constitute successful navigation of the decisions. Working with appropriate subject matter experts, three artifacts for capturing and representing the evolution of knowledge are developed, beginning with the Key Decision Chains, and Knowledge Evolution Summaries, and culminating in the DOSE Knowledge Map. The products of a DOSE analysis are:

1. **Key Decisions**: A minimum set of key cognitive decisions required to navigate the decision problem (in this case the technical study). A key Decision is documented in a Key Decision Product.
2. **Required Information and Judgment:** A description of the information and human judgment (including specific skills and expertise) needed to support those decisions. These are indicated by "Required Information," "Algorithms/Heuristics," "Special Skills or Knowledge," and "Required Expertise" in Figure 10.
3. **Essential Information Products:** A minimum set of information products and content specifications (including human judgment needs) essential to successful completion of the study. These are indicated by "Key Decision Product" in Figure 10.
4. **Knowledge Roadmap:** A knowledge map describing all of the above.
5. **Key Decision Based Process Model:** A derived process model (for executing the study) that is based on the knowledge map, organized around key decision milestones, and designed to generate the essential information products.

A few of the advantages for the use of decision-oriented methods include:

- A study (process) punctuated by the key decisions needed,

- Information products that are truly essential to the derived study process, both of which contribute to

- Simpler, more efficient, derived study processes.

2.4.4 Study Planning Considerations

2.4.4.1 Study Phasing

Breaking the scope of a study into multiple phases may be desirable for a number of reasons including:

- Funding timing and origin may dictate multiple phases

- The scope or necessity of following phases may not be determinable until the results of the first phase are known.

- The customer may need some results faster than others. The phasing is thus based on the timing of customer needs.

- The composition of the study team may change significantly between phases because of the need for different types of and levels of expertise.

Generally, study phases should not be strictly serial, but should overlap somewhat in time. Essentially, the planning for a following phase should occur during the final execution of a previous phase. This helps ensure there is continuity of knowledge or an effective transition of knowledge from one phase to another.

2.4.4.2 Classified, Sensitive and Proprietary Data

In planning a study, active consideration must be given to how the teams will handle Classified, Sensitive, and Proprietary data. These different classifications of data have different rules with respect to information systems and the sharing of data. If the use of Proprietary Data or Competition Sensitive data is anticipated, non-disclosure agreements for all non-government team members are likely required. In some cases, government team members may also be required to sign a non-disclosure agreement.

The structure of the final report may also be influenced by the classified, sensitive and proprietary data. Many times, one would like to share the final report with stakeholders and other potential customers; the inclusion of Classified, Sensitive, and Proprietary data may preclude sharing. Where possible, any data that would unduly restrict the sharing of the final report should be included in an appendix that can easily be omitted from the report. Non-disclosure agreements may be necessary to share appendices containing Proprietary Data or Competition Sensitive data.

2.4.4.3 Dealing with Uncertainty

To deal with uncertainty, one must understand where and how much uncertainty exists within the study methods. One must then understand how this uncertainty will impact the answers to the customer's questions. This uncertainty can be a function of the study tools or processes, or could be inherent in the problem itself. For example, a given analysis tool may be able to predict the resistance of a ship in waves accurate to 10%. If this is not adequate, a different tool or analysis technique could be employed. On the other hand, the precise price of fuel fifty years in the future is unknowable. No improvement in analysis tools will likely reduce the uncertainty in estimated price.

Figure 12 is a an example used in the NAVSEA Alternate Propulsion Study to show the break-even cost of crude oil where nuclear propulsion becomes the more affordable solution for a small surface combatant. This break-even cost is a function of the design features of the ship as well as the manner in which the ship is used (OP-TEMPO)

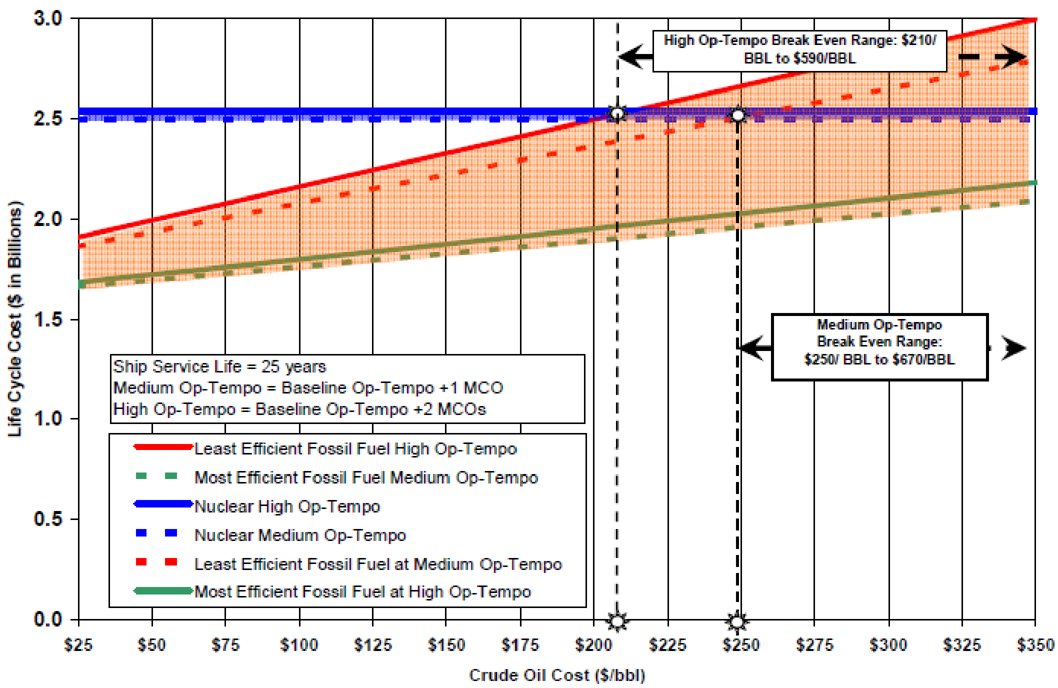

Figure 12: Example of plot depicted impact of uncertainty (Webster et al. 2007)

In planning the work to accomplish the study, it is important to understand what information is needed to generate the plots or other means to convey the customer's answer. Knowing the format of the results, one can then determine what activities are needed to generate the results.

2.4.4.4 Concept Cost Estimates

In many studies, the customer will want to understand cost-performance trade-offs. Within NAVSEA, SEA 05C must certify any potential acquisition program related cost estimate included in a NAVSEA document. Normally this means that SEA 05C or one of their designated contractors should be on the study team to produce the estimates and help guide the study. Alternately, the study team can have its methodology approved by SEA 05C, then submit the final products to SEA 05C for final certification. The study guide should include a description of the data needed by SEA 05C or other cost estimators to produce a cost estimate. This data is typically provided in the form of a formal, serialized memo generally referred to as a "Cost Form."

2.4.4.5 Concept risk evaluation and readiness metrics

In many studies, the customer will want an evaluation of concept risk as well as evaluation of readiness metrics.

A risk statement is generally in the format of a negative event such as "The thermal losses will be greater than can be removed with the current heat exchanger." The risk is evaluated in terms of the severity of the event and the probability of the event. For more information on risk evaluation, see (DOD 2006a).

The two readiness metrics most often evaluated are the Technology Readiness Level (TRL) and Manufacturing Readiness Level (MRL). Information on the TRL can be found in (DOD 2009) Information on the MRL can be found in (DOD 2010).

2.4.4.6 Data certification

Many technical studies are data driven. An important planning consideration is ensuring the validity and applicability of data for the intended use in the study. All data should be traceable to a verified and accountable source. Data that is critical to the study outcome should be certified by the appropriate technical warrant holder and/or program manager as accurate and appropriate for use in the study. This certification is typically in the form of a serialized memorandum from the technical warrant holder / program manager to the study leader. The certification can also take the form of a Design Data Sheet, standard, specification, or handbook.

2.4.4.7 Organizational Structure Considerations

Many factors can influence how a study team is organized. In general, a study leader should strive to get the right expertise on the team. This may result in the study team being geographically dispersed, or composed of individuals from many different organizations. Small studies may be executed completely by a small team of co-located individuals that divide up the work in an ad hoc fashion. Larger studies however, require deliberate thought as to the study organizational structure. Some basic principles in establishing an organizational structure include:

- An activity should be accomplished by a single co-located team. This team may be assigned multiple activities. An individual may be on multiple teams.

- The content of the information passed between activities (and thus the teams) should be well defined.

- Teams associated with activities that form a "cluster" in the study DSM should ideally be co-located. Consideration should be given to automating the transfer of data among the tools used within the activities of the "cluster."

- A study integrator or a Study Integration Team is vital to ensure that the different teams are following the study guides, identifying and making additional assumptions that the teams need to accomplish their activities, managing and facilitating the flow of information among the activities, and controlling the iterations within the DSM "clusters." The Study Integration Team should be the authoritative source for any information concerning the study.

2.4.4.8 Dispersed Workforce

It is not unusual for a study to have team members located throughout the country (if not the world). This dispersed work force can present some challenges (and opportunities). Best practices for working with a dispersed work force include:

- Extensive use of video conferences, web-based conferences, and teleconferences for meetings instead of travel. Generally it is good for the first meeting and the last meeting to be held face to face (to develop a personal relationship), but most other meetings can be held through video conferences and teleconferences. All meetings should be well run by the team leader (or designated leader) with an agenda and meeting minutes (including a list of participants).

- Extensive use of a "shared directory" to enable teams to share working documents, reference documents, and final products. These three classes of documents should be clearly partitioned from each other within the "shared directory".

- Rigorous publishing of meeting minutes and other documents on the "shared directory" to ensure the entire workforce remains current with respect to the progress of the study.

- Where possible, take advantage of radically different time zones to speed the iteration rate of a "cluster." For example if a team on the East coast and a team on the West coast are part of a "cluster," the East coast team could complete its activity by 1 p.m. and forward results to the West coast team where the time would be 10 a.m. The West coast team could complete its activity by the close of business and forward results back to the East coast team for another iteration on the following day. In this manner the study would accomplish 11 hours of work a day without any expenditure of overtime.

2.4.4.9 Validation, Verification, and Accreditation (VV&A) of Design and Analysis Tools

The Navy Modeling and Simulation Office's "Modeling and Simulation Verification, Validation, and Accreditation Implementation Handbook" (NMSO 2004) provides a broad, quick overview of what the VV&A process entails.

Verification. For design and analysis tools the question is "Was the tool built right?" Are the software, data, assumptions and other tool attributes correctly implemented?

Validation. The process of determining the degree to which a tool is an accurate representation of the real world is asking "Was the right tool built?" Are the physics based algorithms faithful to the real world, are the boundary conditions correct, is the embedded data reliable and are other tool requirements correct?

Accreditation. Accreditation answers the question "Is this the right tool to use for this particular study?"

Figure 13 provides a simple pictorial explanation of the VV&A terms defined above.

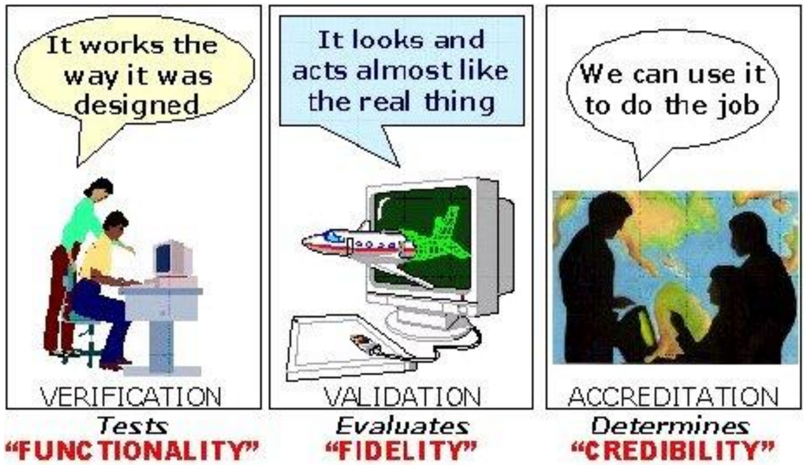

Figure 13: Verification, Validation, and Accreditation (NMSO 2004)

While most studies will not be long enough in duration to conduct formal Verification and Validation of tools, VV&A should be actively considered in the selection of design and analysis tools. The conscientious consideration of VV&A provides credibility and confidence in the results of the study. VV&A for every design and analysis tool used should be addressed in the study guide and in the final report.

2.4.4.10 Generalizing Results

In many cases, the customer is interested in the answer to a generalized question that can be applied broadly. Studies however, tend to look at only a few specific cases. The issue is how to translate the results of the specific case to the more general question. Key to getting this right is understanding the question, and understanding how the answer will be presented to the customer and study stakeholders. Both should be accomplished early and documented in the Study Guide.

One technique that has proven successful is to conduct a design space exploration early using simplified models, then calibrate the resulting response surfaces with higher resolution models at carefully chosen points.

Where possible, use analytic based arguments to describe the sensitivity of point solutions to changes in independent variables. The Customer is often very interested (or should be interested) in understanding how robust the answer presented is to changes in the assumptions.

2.4.4.11 Intermediate Final Products

It is not unusual for a customer to initiate a study when he/she needs the information to make a decision. This means the customer is interested in getting results as fast as possible to enable a decision to be made. Hence the imperative to provide good answers fast. To satisfy this need of the customer, one should consider producing multiple final products throughout the study period to provide answers to the customer's questions as soon as possible. Any final product that is delivered to the customer prior to the commencement of the Study Closeout activity is an intermediate final product.

Without intermediate final products, the tendency is to brief the customer with intermediate results, then not deliver the final product until the end of the study. Unfortunately the customer is often left confused when the intermediate results change in the final report. Providing intermediate final products to the customer can clarify which results are not anticipated to change, and which results require further analysis before finalizing.

Another equally important driver for Intermediate final products is gaining stakeholder buy-in to the results. It is always good to know as early as possible when key stakeholders are not aligned with the way the study is progressing. If problems are identified early, the study guide and study process can generally be slightly modified to address the problem. If identified at the end of the study, time and money will likely be in short supply, and one risks having a "non-concur" with the study results from a key stakeholder.

2.5 Work Tasking

A study leader should be familiar with the many ways to fund the participation of contractors and government engineers to accomplish the study activities. In developing tasking statements, the study leader should consider the following:

- The tasking should include the Activity definitions including inputs, outputs, and the expected activity duration. The tasking should also indicate the number of iterations expected.

- The government should carefully consider what level of Intellectual Property Rights to retain. Inattention to these issues has resulted in the past with the government unable to use the products of work they had contracted for. In this case, the government had to redevelop products using in-house expertise.

- The tasking should include requirements to participate in integration meetings, peer reviews, project reviews, and develop written documents.

- Some contractors and Government organizations have a history of running out of funds before developing the final report. This can be alleviated to some degree by including an option in the contract for follow on work and making it clear that the option will only be exercised if a satisfactory final report is delivered for the base tasking in a timely manner. This tactic does require the study leader to have an alternate plan to accomplish the follow on work should the contractor not deliver the final report.

3. WORK EXECUTION

3.1 Project Management

3.1.1 Cost, Schedule and Performance

For many small / short duration studies where the participants are generally the same throughout the study, the study leader should concentrate on getting the requisite level of quality within the allotted schedule. If this is achieved, costs will also likely be in line with the budgeted amount.

For moderate size and duration studies, cost, schedule, and performance must be more closely monitored by the study leader. The study leader should use tools such as Earned Value Management to help identify potential problems and take early corrective action.

Large projects may invoke a formal Earned Value Management System (EVMS) for implementation throughout the project. Information on EVMS can be found in DOD (2006).

Peer Reviews can be an effective means to gauge the quality of the work performed under the study. The Project Reviews concentrate more on Cost and Schedule Performance.

3.1.2 Risk Management

The study leader should actively access the risks associated with successfully completing the study on time and within budget. While a formal risk management program is likely only desirable for the largest of studies, the study leader should maintain a risk register, incorporate cost effective mitigation plans into the study process, and maintain sufficient contingency funds / resources to cover the risks. See (DOD 2006a) for additional information on risk management.

3.1.3 Reporting and Metrics

Management reporting and metrics are necessary for the effective execution of a moderate to large study. Experience has shown that a monthly status report is not too onerous to the teams, yet is generally timely enough for study management to understand the status of the project. These status reports should include meaningful metrics agreed to between the study leader and the teams accomplishing the activities.

3.1.4 Scope Growth and Growth within Scope

A study leader should be very careful in accepting growth in the scope of work. The scope of work is generally bounded by the work needed to answer the Customer's questions as articulated in the study guide. Any additional work is growth in scope.

Where possible, the study leader should work with the customer to incorporate the increase in scope in a follow on phase to the study. The need for additional funding or resources should be clearly identified in the planning for the follow on phase.

Growth within scope is also possible. Growth within scope occurs when additional wok is needed to answer the Customer’s questions, but that work was not directly budgeted for. For this type of growth, the study leader should strive to accommodate the additional work within the funding and resources provided. Ideally, the study leader will have included sufficient contingency funds (also called "management reserve") in the budget to accommodate the additional work. Resources can also be reallocated from other tasks, if possible. In some cases additional mission-funded personnel can be applied to the study to free up funds for the additional work.

If the growth within scope is so significant that the additional work cannot be accommodated with the resources available to the study leader, then the study leader must work with the Customer to either obtain more resources or reduce the scope of work.

3.2 Work Execution and Integration

Activities are completed in accordance with the Work Tasking and direction from the Study Integrator / Study Integration Team. The Study Integrator / Study Integration Team serves a critical role in ensuring each activity is provided with the needed information and resources to accomplish the activity, in resolving issues spanning multiple activities, and in providing guidance to individual activities to address global study issues. Leaders of individual activities should communicate often with the Study Integrator / Study Integration Team and with the leaders of other tightly coupled (part of the same DSM "cluster") activities. The Study Integrator / Study Integration Team should be informed as quickly as possible of any missing data, missing resources, missing assumptions, or any other issue that impacts the timely completion of the activity within cost.

Careful attention must be paid to ensuring that the individuals accomplishing the study activities are adhering to the key assumptions in the study guide and are producing the products of the requisite quality and in the format required by other study activities.

Often, the need to change the study guide will become apparent during Work Execution and Integration. Typical reasons include the unavailability of needed information, tools or methods not working as anticipated, assumptions found to be inappropriate, and planned resources not being available. The customer and stakeholders should be involved with any modification to the study guide. Changes to the study guide may also result in the need to change work tasking documents.

3.3 Peer Review

Conduct peer review(s) at appropriate time(s). For many studies, peer reviews at the midpoint and 90% completion time (prior to the associated project review) are appropriate. The first allows a mid-course guidance correction to the study once initial data is produced, and the second hopefully will identify potential major mistakes before the study funding and time runs out. Peers should include subject matter experts that have not been directly involved in the conduct of the study. Consensus is not the goal. The goal is independent technical evaluation of the study assumptions, methods, data, and results. If consensus is not achieved, the dissenting inputs should be documented, and may be appropriate to include in the study report.

For short duration studies of a few weeks or less, the peer review may consist of an informal hour meeting with one or more subject matter experts. The results could be documented in a manner such as a memorandum for the record, or even an email. For longer duration studies, the peer review could last a half a day with results documented in formal, serialized meeting minutes.

Inviting the customer is generally recommended; however the peer review should generally still be conducted if the customer is not available.

3.4 Project Review

The number and depth of your meetings and project reviews depends on the duration and complexity of your study. The purposes of these meetings and reviews, however, are the same for simple, short studies as they are for the most involved complex, multi-year studies. They are:

- To communicate study plans, progress, issues, and risks to the customer and other stakeholders
- To make sure that the customer and other stakeholders buy into the process, and by extension, the results
- To make decisions on eliminating options (in Set Based Design this would entail a reduction of the design space) or selecting an option for the next study activity.
- To aide in the free flow of information among team members, the customer, and other stakeholders
- To solicit ideas and feedback from outside the team

Typical project reviews for a 4 month to yearlong study are:

- Kickoff meeting
- Midpoint review
- 90% review

Shorter studies may not have a midpoint review, while longer studies may have additional reviews. The kickoff meeting generally is held when the study guide is finalized or nearly finalized and the study team is in place. The 90% review is generally held when the Work Execution & Integration is almost complete, the final report is nearing completion, and study closeout tasking is about to commence.

3.5 Report Development

Performing a great study without properly documenting it is a terrible waste of resources. The results will be suspect because the assumptions and methodology will be unclear, and any lesson learned will be quickly forgotten. A well documented study will satisfy the Customer by explicitly answering important questions, will serve as powerful evidence to support requirements development, will aide future studies by obviating the need to redo your work, and will provide input into design and analysis tool development.

Write a formal, serialized report. Shorter studies may employ a letter report style where the complete contents of the report are contained in a memorandum from the study leader to the customer. More complex studies should create a formal technical report. Guidance for the format and structure of a formal technical report is contained in ANSI/NISO Z39.18-2005. Each formal report must have a title page, signature page, and report documentation page (Standard Form 298).

The title page should contain the report title, report date, organizational logo(s) of those individuals on the signature page, organizational address of the final approval authority, distribution statement, and classification statement. Guidance for distribution statements can be found in DoDD 5230.24. Whenever possible, a graphic image of the design will be prominently displayed on the title page.

Reports discussing technologies covered under "The International Traffic in Arms Regulations" (Code of Federal Regulation; 22 CFR Ch. I, part 120-130) must also have the following statement on the title page:

"WARNING – This document contains technical data whose export is restricted by the Arms Export Control Act (Title 22, U.S.C. Sec. 2751 et seq.) or the Export Administration Act of 1979, as amended, Title 50, U.S.C., App 2401, et seq. Violations of these export laws are subject to severe criminal penalties. Disseminate per the provisions of OPNAVINST 5510.161."

The executive summary, or lead paragraph for a letter report, must delineate the questions that the customer seeks to have answered, explain why the question is important, and summarize the findings in terms of the specific insights gained.

Ensure the report includes the following:

- Identify the customer and the problem statement
- Articulate the subject context and importance
- Demonstrate that the study results answer the problem statement
- List key assumptions
- Identify tools and methodology used

Incorporating the following into the report is recommended:

- Highlight technical and other programmatic risks
- Describe insights gained and recommendations for further study
- Assess risks of study methodology

Incorporate the study guide either as an appendix, or as a reference.

If there is a substantial “minority opinion” it may be appropriate to capture it in the report. Distribute the report to customers and stakeholders as appropriate via official memo.

The study guide should describe the contents of the final report. The study leader must be mindful of scope growth in the final report. While the format and structure of the final report will likely evolve during the study, the report should remain focused on answering the study questions. If time and resources are available, consideration can be made to documenting other tangential topics uncovered during the course of the study.

Work on the report should start immediately following the kickoff meeting. Progress on the report should be reported at all subsequent project reviews.

3.6 Study Closeout

3.6.1 Formal Review of the Technical Study Report

Every technical study report should be reviewed by the appropriate stakeholders. The reputation of the entire organization, not just the study leader or study participants, is impacted by the quality of the study report. The stakeholder review should ensure that all findings are supported by the evidence within the report and statements of fact are supported by appropriate references.

3.6.2 Presenting to the Customer

Present the results of the study to the customer. Concise, 4-page reports are often more effective than PowerPoint presentations at quickly and reliably transmitting essential quantitative information for the purpose of making sound technical decisions. The use of this format (the "Tufte-style" paper) is encouraged. Tufte-style papers are formatted like a published paper but are restricted to four pages, printed out on one 11x17 sheet and then folded in half. Elements include title, author, executive summary, text, and illustrations. Acknowledgements and references can be included as needed. For more information on Tufte-style papers see (Tufte 2003).

If a PowerPoint presentation is used, follow the presentation guidance detailed in Appendix A.

3.6.3 Disposition of and Archiving Data

Upon completion of a study, retained project data should be put in a long-term accessible electronic format on long-term storage/retrievable electronic media. Consideration should be made to submitting technical reports to the Defense Technical Information Center (DTIC).

Proper disposition of project data is a study leader responsibility. Proper disposition will assure the usefulness of these data so future projects can profit by lessons learned and make use of technical work already performed.

The data to be disposed of by a project generally fall into the following categories:

- Project required deliverables.
- Technical data developed to support deliverables.
- Reference matter acquired for project use.
- Management reports such as fiscal reports and progress reports.

The decision regarding what data are to be retained after completion of a project depends on the potential need or benefit expected for use of these data as

- Reference use to answer questions which may arise during follow on studies,
- Use in current/future studies,
- Use in reproducing results,
- Use in presentations, or
- Of interest to future historians.

Consideration should be given to creating "Memorandums for the Record" to capture work on dead-ends and non-selected options that were not included in other formal reports. This work can be equally as useful in future studies as the work in the final report.

During the course of a project, and particularly at the completion of a project, data should be reviewed and a decision made as to retention or disposition. The following steps are provided as guidance to retaining sufficient data to meet the potential needs identified above while keeping the quantity of data retained to a minimum.

a. Review holdings against deliverable requirements and fill deficiencies.
b. Purge the file of insignificant data, e.g., data not required to meet the potential needs identified above
c. Purge the file of all preliminary documents for which approved finals are on file.
d. Purge the file of documents where the data are contained in other summary documents
e. Segregate, identify, and purge duplicates.

3.6.4 Lessons Learned

Particularly for longer duration studies or studies where new methods or tools are used, consideration should be given to collecting and documenting lessons learned in a serialized letter or memorandum. Where applicable, the lessons learned should provide recommended changes to existing process documents or best practices documents. The lessons learned should also compare the actual cost and schedule to the planned cost and schedule in the original approved study guide.

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APPENDIX A - PRESENTATION GUIDELINES

Title Slide

- Who gave the briefing
- The date of the briefing
- Organizational logo of the presenter
- Good descriptive title
- Who you are giving the brief to (optional)
- Classification and/or Distribution Statement

All Follow on Slides

- Classification and/or Distribution Statement
- Date of the briefing (at least month and year)
- Page Number
- Organizational logo of the presenter
- Last name of presenter (optional)

First Slide (possibly two): Bottom Line Up Front (BLUF)

Address the following:

- Is this for information or is a decision needed?
- What level of participation is required from the audience?
- What is the issue? Present the Study Questions.
- What are the answers?
- If decisions are needed, what are the decisions and the decision options?
- What is the urgency of the decision? What is the impact of not making a decision?

Outline Slide

- Provide an outline for the remainder of the presentation.

Follow On Slides

- Treat each slide as a paragraph – one distinct message per slide. If a slide is extremely busy, it is likely because the slide is attempting to convey multiple messages.
- Because the slides will be used as a reference by the audience after the presentation, the Information needed to convey that one message should be on the slide. Slides should be simple, but not lacking in the required information. Overly abbreviating the message can lead to ambiguity and a failure to accurately convey information to the audience.
- Clearly identify the message for each slide – possibly use bumper stickers.

• Follow a logical progression of messages for the succeeding slides to support the conclusions or provide the necessary knowledge for making a decision.

- Provide sufficient study background and insight from the study.

• Use images instead of words where possible.

• Only include information needed to convey the message – eliminate distracting details.

• Although summarizing the messages of previous slides is acceptable; do not repeat supporting information unless you have a good reason.

Decision Slides

• If a decision is needed, include a decision slide in the appropriate place in the presentation.

• The decision slide should clearly articulate the decision needed and provide check boxes next to the different options.

• During the presentation, consider checking the box for the decision made and have a decision official sign the slide.

Closing the Presentation

• Include a summary – restate study questions and the answers.

• If a decision presentation, review the decision made.

• If applicable, include next steps

Notes

• The reasons for putting the answer up front include:

– Many times you will only have a fraction of the time you originally thought you had. If you get the answer out at the start, you make sure you have conveyed your message.

– By knowing the answer, the audience has the framework to interpret the rest of the slides. Hopefully, you will stop the tendency of the audience to wonder where the presentation is leading them. Many times, your audience will focus on a specific aspect of the solution; this gives you the opportunity to jump to the appropriate slide in the presentation (or even to a backup slide if necessary).

• Leave out data that does not directly address the issue at hand. Many engineers structure their presentation like a photo-album; they present their journey through the study. Unfortunately, while this may be interesting to the presenter, it‘s not effective in rapidly conveying information. Only that information which is central to the conclusions made by the presentation should be incorporated. The presentation should be structured around the conclusions, not the process used to develop the conclusions. In other words, the presentation should be like a story, but the plot of the story should be the topic itself, not the analysis of the topic.

• Be honest. DO NOT suppress information that appears to run counter to your conclusions. Rather, show the information and give the reasons why you believe the information does not invalidate your conclusions.

• Leave out data of questionable quality that support the conclusion of the study. If appropriate, include the data of questionable quality as well as a risk assessment if the data conflicts with conclusion of the study.

- Never use data that you do not understand or cannot clearly explain to support the conclusion of the study. This data can be used in presenting a risk assessment of the validity of the study results.
- Do not read the slides, tell the story. The slides should tell the story on their own, but effective visual communication is very different from effective oral communication. Use the two modes to complement each other, not to repeat each other.
- Use page numbers on all slides. For configuration management reasons, also consider putting the date and filename on all slides. Adding organizational logos to every slide further helps ensure that the originator of a hard copy slide that‘s been faxed multiple times can be determined.
- Have a good understanding of the accuracy of your results.
- When comparing results on options, focus on statistical significance of the differences. If numbers are presented, ensure precision of display does not exceed the accuracy of the metric. Do not claim one option is better than another if the differences in the metrics are not statistically significant.
- Provide interpretations of results. What generalized lessons can be learned? Often we are not concerned with the particular details of the concept studied; rather we are interested on what is learned to impact decisions at hand. Are the results a function of the details or can they provide the generalized answers?
- Do not use too many slides. Use the fewest necessary to make your point. In no case should you have more than 1 slide per minute of presentation. Ideally, the ratio should be about 1 slide per 2 to 3 minutes – it allows you to tell the story and allows the story to be heard instead of just getting through the slides.
- Strive to have an engineering level of detail about an order of magnitude greater than that which is presented. This helps ensure that what you present has a solid foundation, is not just a fantasy, and can likely remain accurate even if one of the lower level details is found to be inaccurate. The increased level of detail could be included in backup charts, should questions come up.
- Reference other sources that you use data from.