

**Conduct
Systems Engineering Trade Studies
Process**

REVIEW DRAFT

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1. **Description**

This document describes the general steps of trade off analysis and the major considerations involved. The process description herein is intended to capture the major elements of a trade study irrespective of the specific acquisition phase or complexity/scope of the system/subsystem/element being analyzed. It is recognized that these factors will be the tailoring influences on how this process is applied in the conduct of the actual study. The descriptions presented are at a moderate level of detail. Each trade off analysis or study is unique and any further breakdown of the subprocesses involved will be dependent on the individual trade off being examined, the issue at hand and the scope of the analysis. A graphic illustration of the trade off process is shown in the Trade Study Process Template, figure 1.

Preceding

4.X Process(es) requiring trade off analyses

Inputs

1. Tasking
2. Problem (i.e., Refined Customer Requirements Design Reference Mission Profiles [4.1.2] Alternative System Functional Architectures [4.1.2] Alternative System Physical Architectures [4.1.2] Requirements and Functional Analysis Decision Data [4.1.2] Design Decision Data [4.1.2] MOEs [1.0, 4.1.2] MNS, ORD, ST AR, TEMP [1.0, 4.1.1] Draft System Design Documentation [4.1.2] ICIDs [4.1.2] CM Plan [4.1.1] Technical Data [Industry, 4.x] SOW [1.0, 4.1.1] Other Trade Studies [Industry, 4.x])

Entry

There are alternatives to be evaluated which are sufficiently complex or important to warrant formal analysis and documentation

Handbooks, Standards,

System Engineering Management Guide // Guidelines for Transition to / Inputs Imposed



CONDUCT TRADE

Purpose

To provide data to support the decision making process for any complex problem where there is more than one alternative. The data may be used to establish system requirements, configurations, budgets and plans. Sitrades integrate results of more focused trades studies performed by other technical specialties.

Critica

Needed to produce quality and cost-effective products.

Primary sub-

- Customer interface and feedback
- Analyze Tasking and define Trade Off
- Define Study Objectives, Requirements, Constraints, and
- Define Trade Study Team
- Identify, Analyze and Evaluate Trade Off Study
- Develop Trade Study
- Identify Alternatives
- Formulate Selection Criteria
- Weight The Criteria
- Define Formats to Illustrate
- Evaluate Alternatives
- Perform Sensitivity Analysis on
- Prepare Trade Study Report with
- Risk Template: Trade

Supporting sub-

Establish and Maintain Design Decision Database // Trade Studies From Technical Disciplines

Agent

4.1.2, other 4.1 elements appropriate 4.x

Tool

Software, Hardware, Mock ups, Prototypes

Metrics and

Customer Satisfaction
Adherence to
Completion of Trade Study

Next

The Process planned to follow Process(es) which required the trade off study

Outputs

Trade Study Reports [1.0, 4.1.1],
Documented Alternative Evaluations [4.1.1],
Recommendations to Modify Inputs [4.1.1],
White Papers [1.0, 4.1.1],

Exit

Trade study objectives requirements are satisfied, documentation exists to support a defensible decision, the customer is

Total Quality Leadership

Figure 1. Trade Study Template

2. **Purpose**

The purpose of this document is to define the Trade Study process as part of the overall System Development & Integration engineering process. This document is intended to be a process tool; to be applied as part of the conduct of a Trade Study by Teams. This process definition is also intended to be a living document; updated following use by Teams to capture process improvements, superior product examples, and lessons-learned.

3. **Owner**

The owner of this process is the Systems Development and Integration Engineering Competency, code 4.1.2.

4. **Agents**

Agents involved with this process can come from any competency within the organization. Primary agent could be a team specially tasked to conduct a directed Tradeoff Analysis, however, any team could execute this process as part of the systems design process (including subsystems and system components). For Platform-level trades, it is envisioned design 4.1.2, other 4.1 elements and the appropriate 4.x elements required to address trade study issues.

5. **Preceding Processes**

Trade Studies can occur at many different times during a system’s life cycle, so there is no single process that will precede the Trade Study. In general, this process will follow some level system definition or design at which point several alternatives become apparent, necessitating a trade study to show the relative benefits and drawbacks, and permit downselect to a preferred alternative or alternatives.

6. **Inputs and Suppliers**

INPUTS

Tasking, Problem Description
System Alternatives
Trade Criteria, Driving Requirement

SUPPLIERS

Program Engineering Management
Design /Development Team
Lead for 4.X process requiring trade off analysis

Tasking is the management directive to initiate the study. The tasking will be directly related to the subject of the trade study. Trade studies can be performed in the areas of requirements, design, approach, organizational structuring, project staffing, component selection, make or buy, balancing considerations such as survivability versus weight, as well as many other; therefore, no more detailed discussion of tasking can be made at this level.

The Problem Description defines the problem to the level at which it is desired by management to initiate the trade study. In order for a trade study to begin the need for it must be recognized, a trade study task defined and some level of problem description produced and supplied to the trade study lead.

7. **Entry Criteria**

To enter a trade study or analysis, alternatives must exist which are sufficiently complex or important to warrant formal analyses and documentation in order to proceed further with the design/development.

7.1 **Required to Start** - Tasking and a problem description are required to start a trade off study. There are no particular system acquisition prerequisites to starting a trade study.

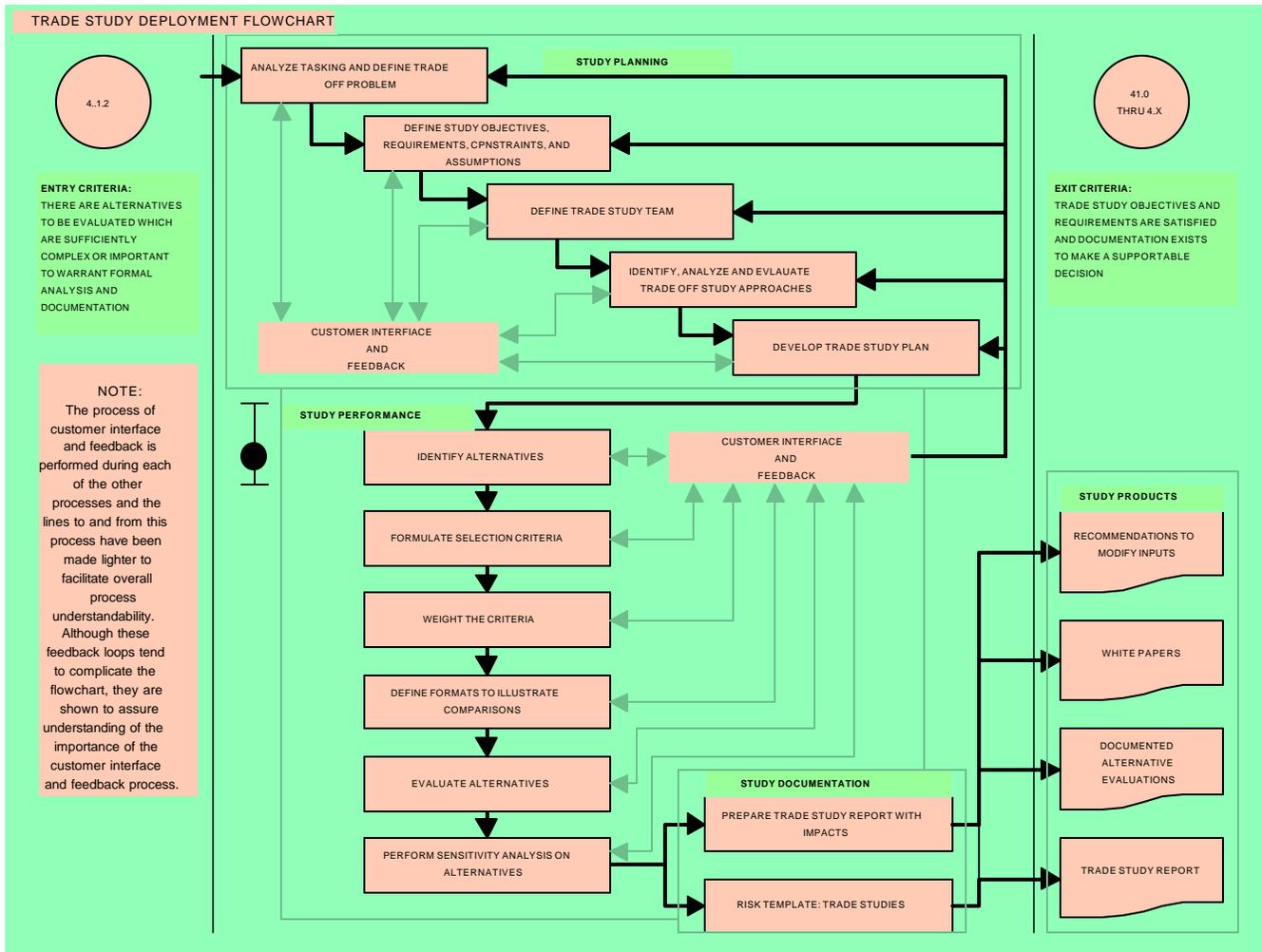
7.2 **Will Cause to Start** - Informal trades will usually self-initiate whenever multiple solutions exist. Formal trade studies will normally be initiated via a request by the Team followed by a formal tasking by engineering management.

8. **Primary Subprocesses** - Primary trade study sub-processes are listed below, refer to the deployment flowchart, figure 2 of the 'Overview section, for an illustration of the relationships among the subprocesses. Particularly important to the trade study process are customer interface and feedback from process phases and subprocesses to other trade study phases and subprocesses.

- Analyze Tasking and define Trade Off Problem
- Define Study Objectives, Requirements, Constraints, and Assumptions
- Identify, Analyze and Evaluate Trade Off Study Approaches
- Define Trade Study Team
- Develop Trade Study Plan
- Identify Alternatives

- Formulate Selection Criteria
- Weight The Criteria
- Define Formats to Illustrate Comparisons
- Evaluate Alternatives
- Perform Sensitivity Analysis on Alternatives
- Prepare Trade Study Report with Impacts
- Risk Template: Trade Studies

8.1 **Overview** - The subprocesses are related as shown in figure 2. Note particularly that there is continual feedback from subprocess to subprocess and to the customer both during the study planning phase and the study performance phase of a trade study.



Note particularly that there is continual feedback from subprocess to subprocess and to the customer both during the study planning phase and the study performance phase of a trade study.

Figure 2. Trade Study Employment Flowchart;

- 8.2 **Analyze Tasking and Define Trade Off Problem**
The purpose of this subprocess is to define the problem. This consists of assuring that the problem is stated in clear and concise terms, that there is nothing missing which is needed, and that there is enough information supplied to enable definition of study objectives, requirements, constraints, and assumptions. It also involves assuring that all information supplied is accurate as far as can be determined, and that there are no hidden assumptions. Additional analysis must be made to assure that the information supplied supports definition of the proper set of disciplines to be involved in the study. Finally, an initial estimate of the ability to maintain cost and schedule constraints or other constraints must be made. This process is highly coupled with the customer interface and feedback subprocess to assure customer agreement of with the tasking analysis. Lack of a complete and accurate assessment and analysis of tasking will lead to eventual failure of the study or to a study restart. This subprocess is performed by the trade study lead or a group of key personnel identified by management or the trade study lead. These key personnel may or may not remain as members of the final trade study team. The owner of this subprocess is 4.1.2.
- 8.3 **Define Study Objectives, Requirements, Constraints, and Assumptions**
The purpose of this subprocess is to define the scope and bounds of the problem. This is a very key subprocess and is also highly coupled with the customer interface and feedback process. All results should be documented and cleared with the customer prior to proceeding. Also involved in this subprocess is adjudication of disagreements with the customer or his agent(s). Final go-ahead should be received from the customer prior to proceeding. This subprocess is performed by the trade study lead or a group of key personnel identified by management or the trade study lead. These key personnel may or may not remain as members of the final trade study team. The owner of this subprocess is 4.1.2.
- 8.4 **Define Trade Study Team**
The purpose of this subprocess is to define the personnel and disciplines required to perform the trade study. The owner of this subprocess is 4.1.2. The team composition should mirror the issues and problems being addressed by the trade study.
- 8.5 **Identify, Analyze and Evaluate Trade Off Study Approaches**
The trade study team must examine all potential approaches to performance of the trade study. This must be done with regard to study objectives, requirements, constraints, and assumptions. The approaches must be compared on the basis of their efficiency in solving the trade study problem.
- 8.6 **Develop Trade Study Plan**
The purpose of this subprocess is to plan the trade study from start to finish, including contingency plans. The plan involves task descriptions, task assignees, a plan schedule and a description of everything accomplished up to this time. The owner of this subprocess is 4.1.2.
- 8.7 **Identify Alternatives**
The purpose of this subprocess is to identify the alternatives to be evaluated. These are the subjects of the trade study and comprise the 'trade space'. The owner of this subprocess is 4.1.2.
- 8.8 **Formulate Selection Criteria**
The purpose of this subprocess is to define the criteria to be used in judging the value or relative value of each alternative. If there is no selection criteria, a form of media depicting relationships amongst the variables may be required. The owner of this subprocess is 4.1.2.
- 8.9 **Weight The Criteria**
The purpose of this subprocess is to define the importance of each selection criteria and to assign appropriate weights. For example, if signature reduction is twice as important as cost, then signature reduction might have a weight of 2, while cost has a weight of 1. The owner of this subprocess is 4.1.2.

8.10 **Define Formats to Illustrate Comparisons**

The purpose of this subprocess is to define the way the results of the study are to be presented in order to easily see and assess the differences in the rank of each alternative. Although preliminary formats should be developed and included in the trade study plan, the actual results obtained may require redefining these formats to assure good illustration of the comparisons.

The owner of this subprocess is 4.1.2.

8.11 **Evaluate Alternatives**

The purpose of this subprocess is to actually evaluate each alternative based using the results of the previous subprocesses.

The owner of this subprocess is 4.1.2.

8.12 **Perform Sensitivity Analysis on Alternatives**

The purpose of this subprocess is to determine the sensitivity of the trade study results to variations in the criteria or criteria weighting or other important trade study variables.

The owner of this subprocess is 4.1.2.

8.13 **Prepare Trade Study Report with Impacts**

The purpose of this subprocess is to document the trade study for future reference and allow for distribution of the results.

The owner of this subprocess is 4.1.2.

8.14 **Risk Template - Trade Studies**

The purpose of this subprocess is to define the risks associated with the trade study and their effect on interpretation of study results.

The owner of this subprocess is 4.1.2.

9. **Supporting Subprocesses**

Supporting sub-processes are:

- Establish and Maintain Design Decision Database
- Archive Trade Studies From Other Technical Disciplines

9.1 Establish and Maintain Design Decision Database

This subprocess supports trade studies by providing a repository of documented decisions and supporting data. This will typically be done by the program team itself and maintained as a management tool.

9.2 Archive Trade Studies From Other Technical Disciplines

This subprocess supports trade studies by providing a repository of existing trade studies for study and reference purposes when performing a new trade study. This can be accomplished by individual competencies as part of their process/capability improvement.

10. **Timeline**

There is no one timeline or schedule nor a generic timeline or schedule for a trade study. The timeline or schedule for conductance of a trade study is dictated by constraints such as:

- The number of available resources
- The time the final decision based on the trade study must be made
- The desired and completeness of the trade study
- The size of the set of alternatives to be examined
- Management constraints
- Situational constraints

The timeline, or schedule, should be examined within the light of the acquisition timeline, if appropriate.

11. **Outputs and Customers** - Trade study outputs and customers are:

OUTPUTS

CUSTOMERS

Trade Study Reports	[1.0, 4.1.1, 4.x]
Documented Alternative Evaluations	[1.0, 4.1.1, 4.x]
Recommendations to Modify Inputs	[1.0, 4.1.1, 4.x]
White Papers	[1.0, 4.1.1, 4.x]

12. **Exit Criteria**

The exit criteria for a trade study are:

- Trade study objectives and requirements are satisfied - typically when relationships between alternatives and relative benefits have been defined to a level of detail sufficient
- Documentation exists to make a supportable decision
- The customer is satisfied.

13. **Next Process(es)** - The next process or processes is that process or those processes which were planned to follow the process requiring the trade study.

14. **Tools**

Tools which are employed in trade off studies must be specifically chosen based upon the nature of the trade off study, however generic tools are:

- Software
- Hardware
- Mockups
- Prototypes

15. **Process Improvement Metrics and Measures**

The metrics and measures used to ascertain success of and improve trade studies are:

- Customer Satisfaction
- Adherence to schedule and time ahead of schedule
- Completion of Trade Study Objectives

16. **Standards and Handbooks**

None.

17. **Applicable Training and Experience**

Applicable training includes an technical/scientific bachelor of science degree (e.g., electrical engineering) and expertise in the scientific or engineering aspects of the subjects of the trade off study. On-the-job experience includes performance of tasks which involved the subject areas of the trade study or performance of, or involvement in, performance of a previous trade study. Training can also be achieved through study of previously performed trade studies and comparison of those trade studies to the trade study process definition contained in this Trade Study Process document.

18. **Reference Material**

18.1 General

General references include:

1. Systems Engineering Management, Achieving Total Quality, pp 41-42, pp 63-64, p 267; James A. Lacy McGraw-Hill, ©1992 by James Lacy
2. Project Management and Systems Engineering Guide, Technical Document 108, Third Edition, 30 March 1994, Naval Command Control and Ocean Surveillance Center, San Diego, CA, pp III-11, IV-1, XI-1, XIII-1, XV-1, XXI-1, et al.
3. Donnell, M. L. and Ulvila, J. W.; "Decision Analysis of Advanced Scout Helicopter Candidates", DTIC Technical Report, Defense Logistics Agency, February 1980.

4. Saate, T. L.; "Analytic Hierarchy Process", McGraw-Hill, 1980.
5. Russon, L. and Streifer, S.; "A Systems Engineering Approach to Support Design of the Navy's SL-7/T-AKR Fast Logistics Support Ship Conversions." Marine Technology, July 1985.
6. DoD 4105.62, "Selection of Contractual Sources for Major Defense Systems".
7. DoD 4245.7-M, "Transition from Development to Production".

18.2 Examples

An example of a trade study is identified below along with remarks on salient attributes of the study. The observations made should be interpreted realizing that the management, the political, or other affecting environmental factors existing in and around the time of the study are not known. Distinction should be made between a 'bad' trade study (one which presents suspect conclusions and recommendations) and one which was poorly documented, and also between a final trade study versus a preliminary one. The examples given were selected specifically to illustrate points and not to reflect on organizations or personnel who sponsored, performed, assisted in, or contributed to the performance of each trade study.

•Annex 1, TRADE STUDY 1:

APPENDIX I, Trade Study of the AN/APN-217(V) Doppler Radar Embedded GPS Navigation System versus the Miniature Airborne GPS Receiver (MAGR) System (Preliminary)

- A clear tasking analysis and statement of the problem is not supplied 'up front' in the trade study document.
- Variations in study approach are not discussed.
- The trade study team is not defined.
- No high-level view of the trade study plan is presented.
- There is no discussion of customer interface and feedback.
- The study does not specifically discuss or identify constraints although they obviously exist (e.g., such as consideration of only two alternatives for whatever reason(s))
- Study assumptions are not addressed.
- The study does not specifically identify the selection criteria in a singular, clear and concise manner or why it was chosen. Additionally, the study does not discuss accuracy of test measurements (errors on data gathered) or resulting effects on the outcome of the study.
- The study does not discuss weighting of the criteria.
- The study does not present a summary or executive summary section providing a study overview. The more important the trade study, the more important it is to include a summary or an executive summary.
- Risk is not discussed as a major part of the study results.
- The shortfalls listed above do not support rendering the technical results of the study suspect, however, the study, at the stage it was examined, needs work and revision to transform it into an exemplary trade study.

19. Voice of the Customer

TBD

20. Voice of the Process

TBD

21. Detailed Process Description

21.1 Analyze Tasking and Define Trade Off Problem;

The tasking must be examined to assure that the problem is well defined and that trade study objectives and requirements can be derived from the tasking. If the problem is not clearly defined, then the trade study lead and consultants of his approval or selection will be required to interface with the customer to arrive at an agreed-upon, clear problem definition. Customer interface is most important during the study planning phase of a trade study, see deployment flowchart for definition of the study planning phase.

21.2 Define Study Objectives, Requirements, Constraints, and Assumptions;

Analysis objectives and requirements must be expressed in precise, explicit terms to serve as the basis for sound decisions. They should define the need, the user, and the constraints bounding the scope of the analysis. The source for these objectives may be systems engineering documentation such as the Functional Flow Block Diagram and Requirements Allocation Sheet (FFBD and RAS). This will provide a firm foundation for identifying the range of alternatives and the decision criteria. Objectives, Requirements, Constraints, and Assumptions must be in concert with overall program, project, or development goals and objectives. Customer interface is very important in this subprocess and continuation of the study should not take place without customer consent.

- Objectives are the high-level object of attainment. A trade study may have one or more objectives. (e.g., The objective of this trade study is to determine the missile seeker technology to be used in a Scud B ballistic missile interceptor to be developed using a non-classical rapid-deployment system development paradigm.)
- Requirements are the quantitative or qualitative attributes which are desired to be achieved. (e.g., Requirement 1: The missile interceptor seeker shall be passive in all modes. Requirement 2: The missile interceptor seeker shall be capable of detecting a boosting Scud B ballistic missile at a range of 80 nautical miles either autonomously or after 'cueing' is provided. Requirement 3: The missile seeker shall be capable of tracking a boosting Scud B ballistic missile from initial detection throughout the boost phase independent of weather.)
- Constraints are limitations imposed on the trade study. (e.g., Constraint 1: The trade study will not consider technology which has not been demonstrated in a prototype system. Constraint 2: The trade study must be completed in 2 months.)
- Assumptions are the 'givens' of the trade study. (e.g., Assumption 1: Any Missile seeker 'Cueing' required will be available. Assumption 2: Missile seeker 'Cueing', if required will be supplied within 5 seconds of a Scud B launch.)

21.3 Identify, Analyze and Evaluate Trade Off Study Approaches;

The trade study team must examine all potential approaches to performance of the trade study. This must be done with regard to study objectives, requirements, constraints, and assumptions. The approaches must be compared on the basis of their efficiency in solving the trade study problem.

21.4 Define Trade Study Team;

The trade study lead must determine how many and what kind of personnel will be required to perform the trade study. The trade study lead may identify particular personnel which will facilitate the trade study due to their experience or knowledge. The trade study team must be introduced to the customer and have customer approval prior to proceeding.

21.5 Develop Trade Study Plan;

A trade study plan must be developed by the trade study team; this plan must:

- Clearly state the problem
- State the trade study requirements, objectives, constraints, and entry/exit criteria
- State the composition of the trade study team and the rationale for team composition
- Depict the trade study schedule with appropriate milestones
- Identify and categorize trade study costs
- Depict how costs will be tracked
- Identify all trade study products
- Delineate the customer interface planned
- Identify appropriate metrics for measurement of trades study performance
- Depict how the study progress will be tracked
- Identify the tools to be used
- Depict how configuration management will be performed
- Depict the handling of changes which may be required in the trade study resulting from interim results or changed circumstances

21.6 Identify Alternatives;

Alternative solutions for consideration may be either predetermined (as in the case of a design competition, there will be the various proposed designs to be examined via the trade off processes) or alternatives developed specifically for the trade study. Candidate alternatives may be the product of systems engineering synthesis activities and represent existing (standard), modified, or original solutions. Candidate alternative solutions should reflect the widest possible range of distinctly different solutions if the overall goal of optimized system design is to be achieved.

Candidate alternatives identified through unconstrained synthesis or brainstorming may be rated based on their ability to solve the problem. Any process used to identify alternatives should assure that study resources are not wasted on nonproductive solutions. Additional ratings or screenings may be performed on the basis of important attributes of the problem. (i.e., schedule, budget). All the candidate alternative solutions must be achievable within study constraints (i.e., time and budgetary constraints). Candidate alternative solutions surviving all screening processes become the decision alternatives. These alternatives are described and documented fully and carefully as well as those alternatives not chosen. Sufficient detail must be available to judge the relative worth of each workable, attainable alternative. If an insufficient number of candidate alternatives survives the screening process, the study constraints should be reexamined and all candidate alternatives re-screened, or the synthesis and possibly functional analysis activity must be re-initiated; this involves study feedback and customer interface.

21.7 Formulate Selection Criteria;

Selection criteria are standards for judging achievement of objectives and requirements. The criteria may include quantitative goals (desired value of the attribute), where possible, and thresholds beyond which the characteristic is unsatisfactory (specification limits). Good selection criteria must:

- Differentiate meaningfully between alternatives without bias
- Relate directly to purpose of the trade-off analysis, including established requirements and high-interest concerns
- Be stated as broadly as possible
- Be able to be measured or estimated at reasonable cost
- Be independent of each other at all levels
- Be understood by evaluators (i.e., customers and management).
- Not be based upon assumptions

Selection criteria may be drawn from systems engineering documentation based on program requirements, military and department guidance and standards, design-for and specialty requirements, and various other supporting documentation. These sources vary in importance based on the type and stage of the effort which spawned the trade study. Regardless of the sources used, final selection must be made by the trade study lead and the customer. The value of the trade-off analysis effort is proportional to the trade study lead and customer's ability and willingness to include all objective and subjective decision criteria. Regular, efficient guidance on decision analysis and appropriate decision criteria is one of the primary products of the systems engineering organization. The outcome of the trade study is directly dependent on the selection criteria used, therefore, the recommended approach is to examine sensitivity of the trade study outcome to the selection criteria used. This process involves feedback (iteration) to other trade subprocesses.

21.8 Weight The Criteria;

Selection criteria are weighted by the trade study team according to their relative importance in impacting the effectiveness of alternatives. To ensure the objectivity of the subsequent analysis, weighting factors developed by the trade study team may be withheld from the analysts who do the evaluation of the alternative solutions. The weighting process has a direct effect on the final outcome of the trade study. If weighting of the criteria is not objective, the outcome of the trade study will be slanted. Sensitivity of the trade study outcome to weighting variations should be assessed.

21.9 Define Formats to Illustrate Comparisons;

Efficient formats to convey trade study results must be developed by the study team. These formats must be amenable to rapid change and evolution since the first format schema chosen will likely undergo modification prior to finalization. Example formats include but are not limited to:

- Utility functions in graphical format
- Multiple axis and multi-variate plots of requirements versus alternatives
- Measure of effectiveness graphical or tabular comparisons
- Figure of merit definition and comparison
- Tabular scoring and comparison
- Qualitative ranking on a bar chart (e.g., 'high', 'medium', 'low')

Formats may involve absolute scaling, ratio scaling, or relative scaling. Formats for a given trade study must use consistent comparisons or scales (e.g., between 0 and 1) so as not to inadvertently weight the scores. Formats must be designed not to inadvertently misrepresent or mislead.

Trade studies involving non technical parameters (such as cost, development time, political saleability) only allow for subjective (e.g., high, medium, low) evaluation. If a discipline such as safety was an essential trade study criterion, it could be represented as a relatively scaled attribute comparison. Quantitative valuations for such criteria could be based upon the results of application of the 'delphi' or a modified 'delphi' technique.

In trade studies which are particularly complex, much time and thought may be required to arrive at efficient and understandable formats for comparison. It may be desirable to form a 'murder board' to provide initial feedback on candidate formats.

21.10 Evaluate Alternatives;

After formats have been defined and agreed upon amongst the study lead, the study team, and the customer, the performance of each alternative is determined with respect to each criterion. Performance determinations or estimates are produced by evaluators utilizing testing, vendor sources, parametric analysis, simulation, experience, comparison, or other available, appropriate and dependable methods. The study lead and the study team must be aware of the accuracy of all data used and be prepared to indicate confidence intervals or confidence factors if such are requested.

21.11 Perform Sensitivity Analysis on Alternatives;

A sensitivity analysis must be performed to determine the effect of variations in any of the trade study variables. When the weighted scores of several alternatives are proximate, a small change in the estimated performance of any alternative against any criterion may change the ranking of the alternatives. The same effect can be caused by slight variations in the weights. In this situation, confidence in data is immensely important as is the ability to adequately defend the approach, estimates, methodology, and data. When the accuracy or confidence limits of the performance evaluation affect the trade study outcome, several options are available to the trade study lead:

- Petition management for a delay in the trade study process until additional information is available.
- Acquire additional data or refine analysis to reduce uncertainty.
- Review criteria and weights for modification.
- Acquire insurance or back-up capability (e.g., parallel development plans).

21.12 Prepare Trade Study Report with Impacts;

Trade Study Reports (TSRs) are used by all decision-making levels from the systems engineering organization through the government program office, Program Manager, and headquarters. TSRs document the trade study and support the decision process. They are used to correlate characteristics of alternative solutions to the requirements and constraints which established the selection criteria for a specific trade study area. Each report documents the rationale used in the decision process and should present risk assessment and risk avoidance considerations as well as impacts of choosing the recommended alternative. Each report should document each subprocess composing the trade study process. The report format and depth should be coordinated between the trade study lead and team with the customer.

TSRs are important contributors to the formal technical review process. As with all systems engineering documentation, the focus and level of detail changes as a program moves through the acquisition life cycle. For example, in conjunction with a System Requirements Review (SRR), equipment concepts related to specific functions such as fail-safe concepts, fault isolation, or target acquisition. A Critical Design Review (CDR) may include trade studies for selection of manufacturing processes. Trade studies can provide valuable support to many specialty areas, such as in the evaluation of risk alternatives. It is important for all trade studies to use common criteria and common relative weighting whether they are for risk management, reliability and

maintainability, integrated logistic support, or other specialty areas. This will ensure a common baseline for all decisions.

21.13 Risk Template - Trade Studies:

This subprocess involves development of a risk templates. A template is simply description of each area of risk, an outline for reducing risk, and a timeline that shows the risk area's relationship to the system acquisition process or other appropriate processes. For reference, see DOD 4245.7-M which provides a detailed description of risk management along with a sample risk template. Each template contains a description of the area of risk, an outline for reducing risk, and a time line that shows the risk area's relation to the system acquisition cycle. Confidence in the risk assessments must be determined, documented, and communicated to the customer and management.

22. Expert Advice

- Assure that the confidence on all data involved in the trade study is known or estimated accurately and objectively and its effect on the outcome accurately assessed.
- Recognize tacit assumptions
- Consider subsequent steps in a development while performing trades studies on a current step or phase. (i.e., trade studies during design should consider alternative manufacturing processes)
- Utilize past trade studies and academic documentation for reference and ideas (e.g., DSEM8600, Program Manager's Checklist for Review of Trade-Off Planning and Studies, figure 8-12)
- Keep the customer and management totally and honestly informed during the entire course of the trade study
- Keep a notebook such as an Engineer's note book from the very beginning of the study until study completion or termination. Potential benefits of a notebook include:
 - Patent rights
 - Applications to future trade studies
 - Defense of actions taken
 - Information for anyone who joins the project
 - General future reference

Document at least the following:

- Instructions
 - Dates
 - findings
 - Decisions, new or revised orders and changes in direction
 - Reasons
 - Team changes such as numbers and turnover
 - Conclusions
 - Changes in any of the above
- Formulate and document a checklist of things needed to be done during each subprocess. Check off things done as they occur, this helps assure nothing is left undone.
 - Maintain configuration control on all appropriate aspects of the trade study
 - Do not use new technology unless it is assessed with trade studies.
 - Formally document all trade studies to ensure engineering traceability to design characteristics downstream
 - Retain all solutions "eliminated" through trade studies in order to revert back to a previous point in the study or to consider them one more time during the final trade study

23. **Lessons Learned**

- Trade studies should consider all alternatives; if they do not, the results may not provide the most efficient or optimal solution.
- Extend and augment trade studies conducted during the conceptual phase with those conducted by the government and concept-phase contractor personnel.
- Fully validate new technology prior to design solidification.
- Trade studies which involve constraints for some reason may be already aiming at a desired solution rather than being unbiased.
- Design policies which do not provide for or recognize the need for trade studies should be suspected of being flawed.
- Qualitative comparison criteria will likely become subject to argument and must be defensible, therefore, anticipate questions and prepare answers beforehand; this includes 'what if' questions.
- Beware of trade study procedures which fail to establish specific schedules and guidelines, identify responsible individuals, define levels of reporting, or have clear objectives.
- Trade studies may be required at any point in a development cycle, i.e., from birth to death, not just in a particular development stage

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