JOINT TEST AND EVALUATION METHODOLOGY (JTEM)

ANALYST'S HANDBOOK FOR TESTING IN A JOINT ENVIRONMENT

Approved By:
Maximo Lorenzo
Joint Test Director
JTEM JT&E

Maximo Lorenzo

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OPERATIONAL TEST
AND EVALUATION

OFFICE OF THE SECRETARY OF DEFENSE
1700 DEFENSE PENTAGON
WASHINGTON, DC 20301-1700

OSD-JT&E

SUBJECT: The Capability Test Methodology (CTM) for Testing in a Joint Environment

The Department of Defense is transforming the way it uses and acquires new systems and capabilities. New weapon systems, force structure, and doctrine are increasingly "born joint." Effective test and evaluation is becoming more difficult across the entire acquisition process as individual platforms become part of complex, networked system of systems that should interoperate and depend upon each other in a battlespace made up of air, land, and maritime forces.

Recognizing these challenges, the Deputy Secretary of Defense approved a Testing in a Joint Environment Roadmap that addresses test infrastructure and standards, methods and processes, and policy and assigned the Director, Operational Test and Evaluation (DOT&E), the responsibility of overseeing its implementation. Subsequently, DOT&E chartered the Joint Test and Evaluation Methodology (JTEM) Joint Test and Evaluation to develop and test a methodology to support conducting the test and evaluation of an acquisition system or system of systems in a distributed joint environment using live, virtual, and constructive elements.

In response to this charter, the JTEM JT&E has developed the Capability Test Methodology (CTM), which is encapsulated in the following three handbooks: *Program Manager's Handbook for Testing in a Joint Environment, Action Officer's Handbook for Testing in a Joint Environment,* and *Analyst's Handbook for Testing in a Joint Environment*. These three CTM handbooks are designed to provide best practices to augment existing Service methods and processes for testing in this new environment. The recommended processes can be scaled as needed to accommodate different sizes and types of acquisitions. The CTM is a comprehensive approach, but also offers individual processes that can be integrated with existing Service methods.

These processes will be updated with lessons learned from the components. Feedback should be addressed to the Director, Operational Test and Evaluation, 1700 Defense Pentagon, Room 1D548, Washington, DC, 20301-1700.

M.D. Crisp
Deputy Director, Air Warfare
Operational Test and Evaluation

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FOREWORD

Purpose

The Joint Test and Evaluation Methodology (JTEM) *Analyst's Handbook for Testing in a Joint Environment (*Analyst's Handbook) provides analysts with the information, guidance, tools, and resources to enable effective system testing and mission level evaluation in an operationally realistic Joint Mission Environment (JME). It focuses on the evaluation of systems and system of systems (SoS) contributions to joint mission effectiveness (JMe) using the JTEM developed Capability Test Methodology (CTM). It is not designed to replace similar evaluator handbooks in use at Service test agencies, but to supplement them in evaluating systems contributions to joint task performance and JMe. In fact, this handbook assumes a general level of analytical expertise implied by the Service handbooks in test and evaluation of systems. We reference the Service handbooks occasionally throughout, we encourage readers to familiarize themselves with their content since they contain a great deal of information that could be useful throughout the JMe analysis process.

Intent

This Analyst's Handbook is intended for test agency analysts and program managers who are participating in joint-level testing of capabilities. In particular, this handbook concentrates on the tasks and objectives of those analysts who will participate in planning for and analysis of systems and system of systems tested in a joint mission environment. Thus, the handbook has a holistic focus on the planning, execution, and reporting of systems and system of systems testing from an analysis perspective.

By referring to this handbook, the analyst should be able to plan, design, execute, and evaluate the performance of systems and SoS in a way that provides traceability throughout the test and evaluation life cycle. Following the guidance contained herein should help the analysis team ensure that all aspects of the test and evaluation (T&E) process are integrated synergistically to provide insights, findings, and recommendations relevant to the critical operational issues (COI) and critical capability issues (CCI) that apply to the system(s) and SoS under test.

The Analyst's Handbook is a working document that is updated as new insights into T&E of systems and SoS at the joint capability level are developed. It should serve as a quick reference guide for the analyst, not necessarily a document that should be read from cover to cover. Much of the material is process-oriented, with discussions and checklists designed to step the analyst through the recommended procedures. Additional guidance and technical details are included in the annexes.

Assumptions

The following are the key assumptions that underlie the development of this handbook:

- The user of this handbook has a basic understanding of probability, statistics, experimental design, and analysis generally commensurate with that expected of test and evaluation analysts at the service level.

- The joint testing of interest is intended to evaluate systems that exist within an SoS, which provide a joint capability.
- The joint SoS enables the accomplishment of joint tasks.
- The joint SoS contributes to JMe.
- Joint missions, end states, objectives, and scenarios are defined by the Analytic Agenda process, Defense Planning Scenarios (DPS), and other authoritative sources.
- The system and SoS under test follows the Joint Capabilities Integration Development System (JCIDS).
- The joint capability of interest can be mapped to Joint Capability Areas (JCA).

General Outline

The information is presented within the context of the CTM, developed by the JTEM JT&E. Thus, the handbook begins with the first chapter providing a brief overview of the CTM and its evaluation thread. Subsequent chapters are organized by CTM steps and processes. Detailed information is captured in the annexes.

As this handbook focuses on the evaluation thread of the CTM, the reader may wish to refer to other documentation developed by the JTEM staff to gain a further understanding of the CTM and related methods and processes. The *Program Manager's Handbook for Testing in a Joint Environment* (Program Manager's Handbook) provides a brief introduction to testing in a joint environment to acquisition program managers, their executive staff, and key members of the testing and evaluation teams. The *Action Officer's Handbook for Testing in a Joint Environment* (Action Officer's Handbook) includes all of the detailed guidance, templates, and checklists required to support system engineers, test planners, data managers, and other members of the program test Integrated Product Team (IPT) in their execution of the program acquisition life cycle.

Any reference to responsibilities in this handbook is purely based on the processes that exist within each thread (analysts perform evaluation thread, system engineers perform systems engineering thread). Service doctrine and organization vary across Services, therefore, the personnel and organizations that fill those roles may vary.

Getting Started

The entire evaluation thread to the CTM is captured in chapters 2 through 6. For each of the primary analytical processes, the following information is provided:

- **Purpose:** Purpose of the process.
- **Discussion:** Includes a general discussion of the overall process, to include its component steps and an overview of what the expected products will be.
- **Tools and Techniques:** A summary list of the tools and techniques that may support the activities, some of which are described in detail in the annexes. While the authors have tried to compile a comprehensive set of potential tools and techniques, this section is certainly not all-inclusive, but should give the analyst an idea of potential supporting tools and techniques.

- **Inputs:** Describes the primary inputs into the process, including the sources of the inputs and a brief description of them. It may also refer the reader to other sections or external resources that may provide greater detail.
- **Checklist:** Included as a figure in the inputs section. It provides a step-by-step checklist to assist the analyst in following the main steps of the process. It can be helpful for ensuring that key steps are not omitted.
- **Actions:** Tells the analyst "what to do." It describes each action in a general level to understand the process. If additional detailed instructions are available in the annexes, then it will reference the appropriate annex. The analyst must determine what level of effort is needed for each action based on the joint capability under test.
- **Products:** Describes the primary outputs and resulting products of the process, including brief descriptions. The information provided in this section is a summary of the previous discussions, which should provide the detail concerning development of outputs.

The handbook also includes a series of annexes that provide additional information. Some of these annexes are referenced directly in the text; in others, such as the acronyms and the references annexes, the reader should be aware that the resource is available. Each annex is described below:

- **Annex A – Acronyms and Abbreviations:** List of the acronyms and abbreviations used in this handbook and its annexes.
- **Annex B – Develop Evaluation Strategy:** Detailed directions for the development of an evaluation strategy for a joint capability.
- **Annex C – Exploratory Analysis:** Detailed discussion of exploratory analysis methods and processes that can be used to analyze and prioritize test factors prior to characterizing and planning a live, virtual, constructive distributed environment (LVC-DE) test.
- **Annex D – Design of Experiments (DOE):** Detailed information on DOE techniques that can aid in reducing T&E requirements for complex SoS and large test designs.
- **Annex E – Capability Crosswalk:** Directions for developing a capability crosswalk, which maps critical T&E issues to mission-desired effects, tasks, conditions, and system/SoS elements.
- **Annex F – Integrated Data Requirements List (IDRL):** Sample IDRL and instructions for developing one for evaluation joint capabilities.
- **Annex G – Analysis Techniques:** Detailed information of analysis tools and techniques that can be used to conduct an evaluation of a joint capability.
- **Annex H – DoD Architecture Framework (DoDAF):** Explanation of DoDAF products and their use within the evaluation thread.
- **Annex I – Sample Data Management Plan (DMP):** Sample outline of the DMP to use for developing actual plans.
- **Annex J – Sample Data Analysis Plan (DAP):** Sample outline of the DAP to use for developing actual plans.
- **Annex K – Sample Joint Capability Evaluation Report (JCER):** Sample outline of the JCER to use for developing actual reports.

- **Annex L – CTM Lexicon:** CTM Lexicon with brief definitions of key technical, mathematical, and statistical terms used in this handbook and in some of its annexes.
- **Annex M – Characteristics and Attributes:** Consolidated list of SoS and system characteristics and attributes extracted from joint and Service doctrine.
- **Annex N – References:** List of the references cited elsewhere in the handbook and its annexes.
- **Annex O – Checklists:** Repeat of the checklists provided in the handbook chapters, intended to be copied and used by the analyst as an aid in conducting and executing the evaluation thread.

Note: In order to facilitate on-line navigation throughout the document, the reader may choose to follow the hyperlinks, identified in blue, underlined text. The reader may also choose to print the handbook and use it in hardcopy.

Role of the Analyst

Within the JTEM CTM, the analyst has primary responsibility for the evaluation thread within the overall methodology. As such, any reference to the analyst or analyst team in this handbook refers to those with responsibility for the evaluation methods and processes. The analysis team is part of the larger joint T&E group, whose responsibilities encompass the planning, execution, evaluation, and reporting associated with testing a joint capability. The larger group may be composed of other teams with responsibility for the operational concept, test design, systems engineering, test coordination, and test execution aspects of T&E processes.

Members of the analysis team will likely have varied backgrounds and experiences. They may have expertise in the fields of operations research, statistics, T&E, systems engineering, decision analysis, business administration, or other fields. They may be members of the acquisition, analytical, operational force, or T&E communities. Each member contributes his background and experience to the overall team. There is no single set of knowledge, skills, and abilities that are prerequisites to membership in the analysis team.

There are, however, some commonalities in the role of the analyst. The analysis team members must use their knowledge, skills, and abilities to translate operational guidance and concepts into an analytical plan for assessing and evaluating the contributions of systems and SoS to joint missions and tasks. They must be able to identify and define the factors that may impact systems and SoS performance and the measures they will use to assess:

- System effectiveness, suitability, and survivability
- SoS performance of joint tasks
- SoS impacts on joint mission effectiveness (JMe)

The analysis team must use the analytical tools at their disposal to identify the most critical factors that should be explored during live, virtual, constructive (LVC) testing. They should then assist in developing the test concept and test plans. After the conclusion of the test, the analyst will examine the resulting data to draw insights and make recommendations concerning the systems under test. The role of the analyst is tightly intertwined with the overall T&E process

(DT&E and OT&E), and is central to the determination of the overall assessment of systems and SoS that provide joint capabilities.

This handbook is designed to assist the analysis team members in their role. It provides detailed instructions and suggests potential techniques for conducting analyses throughout the methodology. It does not supplant the expertise that already resides within the team, but should complement it.

Benefits

First, it gives the analysis team an understanding of its role in the overall process and how its efforts contribute to the success of the overall process. Second, it provides the analyst with a systematic, step-by-step guide for executing the evaluation thread of the CTM from start to finish. Thus, the analyst can use this handbook, with its checklists and discussions, to ensure that the required processes are conducted in the proper order and without accidental omissions. Third, this handbook provides the analysis team with a single, comprehensive resource of best practices. While they are certainly not all-inclusive, the best practices described in this document should, at a minimum, point the team in the right direction and suggest other possible approaches that can be found in other sources.

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1
CAPABILITY TEST METHODOLOGY (CTM) OVERVIEW

1.1 Introduction

Traditionally Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E) are conducted on system operational effectiveness, suitability, and survivability with a focus on materiel acquisition. However, the Joint Capabilities Integration and Development System (JCIDS) process now requires the Department of Defense (DoD) to assess joint capability requirements prior to any acquisition decision points and to use the joint military capability needs as the basis for the development and production of acquisition programs. This will require future testing of systems to be capability focused. Test and evaluation (T&E) will be more complex, to include evaluation of system of systems (SoS) performance, joint task performance, and joint mission effectiveness (JMe). The focus should not only be on the materiel aspects of the systems and SoS levels but should include non-materiel aspects of doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF). The inclusion of these joint capability test requirements will add substantial complexity to the T&E process. It will require innovative design of experiment (DOE) practices as well as a distributed live, virtual, constructive (LVC) test environment to focus limited test resources on critical test factors.

As individual platforms become part of a complex inter-dependent SoS, the operational context in which those systems must be tested needs to be in a joint battlespace. The DoD Instruction (DoDI) 5000.2, E.6.1.d (December 8, 2008) states: "Systems that provide capabilities for joint missions shall be tested in the expected joint operational environment." For T&E purposes, the joint battlespace is described by the term joint mission environment (JME). The JME is defined as "a subset of the joint operational environment composed of force and non-force entities; conditions, circumstances and influences within which forces employ capabilities to execute joint tasks to meet a specific mission objective."[1] Note that this definition of the JME requires descriptions of forces, conditions, joint tasks, and mission objectives. This will be integral to the evaluation thread and the understanding of the joint operational context for test.

The solution to these requirements and problem areas is an approach called the Capability Test Methodology (CTM). The overall goal of the CTM is to provide recommended "Best Practices" for a consistent approach to describing, building, and using an appropriate representation of a particular JME across the acquisition life cycle. From an analyst perspective, the CTM enables effective systems testing in a realistic JME that will allow for the evaluation of system contributions to SoS performance, joint task performance, and JMe.

This Joint Test and Evaluation Methodology's (JTEM) *Analyst's Handbook for Testing in a Joint Environment* (Analyst's Handbook) provides analysts step-by-step instructions and resources for evaluating systems and SoS contributions to JMe in a JME using the CTM methods and processes.

[1] Testing in a Joint Environment Roadmap Steering Group (TSSG), 26 June 2008.

In order to provide conceptual consistency and an underlying business rule structure for the CTM, JTEM employs an ontology approach. An ontology can be defined as "an explicit formal specification of how to represent the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them." In keeping with this definition, the ontology supporting the CTM evaluation thread incorporates a *CTM Lexicon* to provide underlying conceptual definitions for the CTM. The *CTM Lexicon* is a cross-domain dictionary of CTM-relevant DoD terminology and definitions. Authoritative DoD sources are used, where possible, for JTEM terms and definitions. Annex L contains the current CTM Lexicon.

1.2 Capability Test Methodology (CTM) Overview

The CTM was created to address the previously mentioned problems and to deliver a joint capability T&E process that can be used across the acquisition life cycle.

1.2.1 What Is the Capability Test Methodology (CTM)?

The CTM is a six-step testing process designed to incorporate best practices from Service testing with joint guidance, methods, and processes. These steps include:

1. Develop T&E Strategy
2. Characterize Test
3. Plan Test
4. Implement LVC-DE
5. Manage Test Execution
6. Evaluate Capability

These steps are generally in sequence, however, there are interactions between steps which cross this flow pattern. Figure 1-1 provides an overarching view of the CTM process steps, with some of the major products generated during the steps.

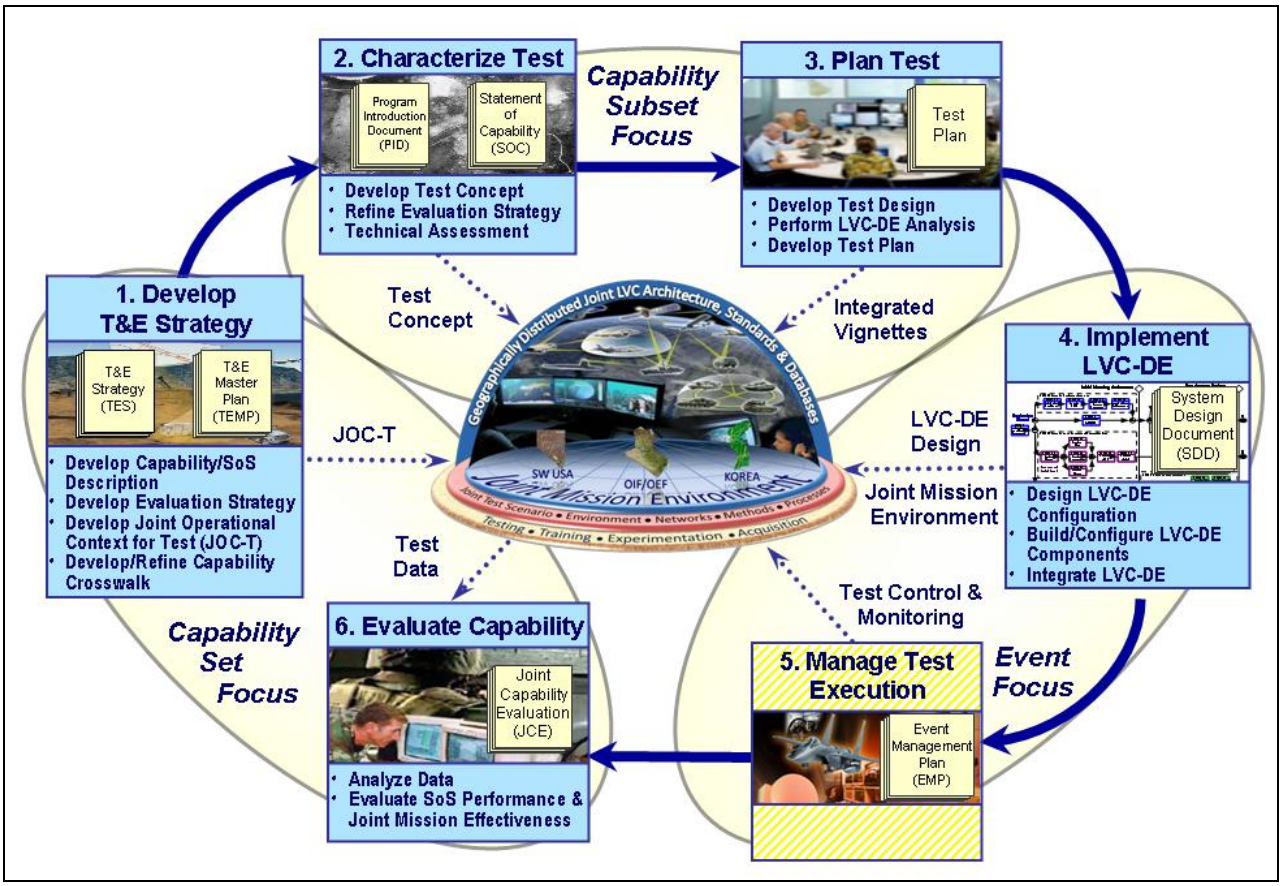

Figure 1-1. CTM Process Steps

The CTM is a rational process that leads participants through the test planning process to tailor and optimize a test to demonstrate joint capabilities. It tests systems or capabilities, Service or joint, and augments existing DoD and Service test processes (tailored to need), it aligns T&E aspects and information across multiple DoD processes, namely Analytic Agenda, JCIDS, DoD Architecture Framework (DoDAF), and the Defense Acquisition System. It also provides recommended best practices for a consistent approach to describing, building, and using an appropriate representation of a particular JME across the acquisition life cycle, and reflects current acquisition policies and instructions.

There are three focus areas (capability set, capability sub-set, and event) identified in Figure 1-1. The higher, more comprehensive focus area is on the capability. In this area, the first and last steps of the CTM, Step 1 and Step 6, are oriented on the overall joint capability under test. In these steps, the analyst develops an evaluation strategy and conducts an evaluation across a campaign of tests on SoS and Service systems that make up the overall joint capability. The second focus area is on a sub-set of the capability, where CTM Steps 2 and 3 characterize and plan capability T&E designs on a selected sub-set of the SoS, SoS attributes, system attributes, joint tasks, conditions, and mission-desired effects. The analyst is generally involved in identifying relevant test issues in the capability evaluation strategy that will be a part of the sub-set focus area and test design for one or more test events. The third focus area is on the event itself: developing an LVC-DE in CTM Step 4 and event

execution in Step 5. The analyst participates in the conduct of these steps but is primarily involved to ensure the event provides the data required for analysis. Once the event has been completed, the evaluation in Step 6 results from the event data, but the evaluation is not only on the capability sub-set, but on the overall capability as well. This evaluation then feeds back into the capability evaluation strategy in Step 1. Refinements may occur in the evaluation strategy and the CTM steps repeated as other sub-sets are planned and executed in the campaign of test events for the capability.

Figure 1-2 displays the first level of the CTM with the six primary steps shown in the blue boxes. Although the steps appear sequential in this figure, there are additional information flows between various steps in the process that occur simultaneously. Decision points and planning conferences are represented by the diamond shapes and are a combination of three different schedule paradigms: test, development, and exercise. It is important for the analyst to complete the analytical products, as listed in the appropriate section's checklist, prior to these events. Traditional test decision point actitivies include a review of the test concept and test plan, a test readiness review and a new decision point called the Joint Capability Evaluation review. These are represented by the diamonds shaded in purple, shown on the bottom row of diamonds. Development decision point activities include the reviewing the logical and physical designs. These are represented by the diamonds shaded in red on the middle row. The exercise paradigm includes activities such as an initial planning conference, mid-planning conference, and final planning conference. They are shaded in green, displayed on the top row of diamonds. These conferences are a useful constructs for larger or more complex programs that involve a broad LVC-DE with numerous participants. This synthesis of three different approaches to management is helpful since the creation of a JME involves test management, LVC-DE development activity, and (in some cases) a large distributed event much like an exercise. The *Action Officer's Handbook for Testing in a Joint Environment* (Action Officer's Handbook) and the *Program Manager's Handbook for Testing in a Joint Environment* (Program Manager's Handbook) contain additional information on the three paradigms. The following chapters will cover additional information flows in more detail.

The entry criteria for each decision point are the products of each process in the applicable CTM step. DP 1 occurs at the end of CTM 1 with the primary purpose of validating the JOC-T and previewing the evaluation strategy with appropriate stakeholders. Approval of the JOC-T as the referent is critical at this point to allow subsequent LVC-DE development. DP 2 occurs at the end of CTM 2. This milestone reviews the test concept, refined evaluation strategy and the technical recommendation for resourcing the LVC DE. This review/conference is necessary to establish the baseline resources needed to instantiate the required JME. DP 3 occurs at the end of CTM 3 with the production of the test plan and detailed operational and functional systems engineering description of the LVC DE. This review verifies and validates the scenarios and vignettes and solidifies roles and responsibilities. DP 4 is a focused engineering review that verifies and validates the LVC DE logical design. DP 5 verifies and validates the physical design and establishes the EMP. DP 6 reviews the VV&A of the instantiated LVC-DE as representative of the intended JME and addresses the readiness of the test team and participants for execution. This review includes such traditional concerns as logistical readiness, safety, limitations, etc. DP 7

examines the results of the test for all applicable stakeholders and is the culmination of CTM 5 and CTM 6.

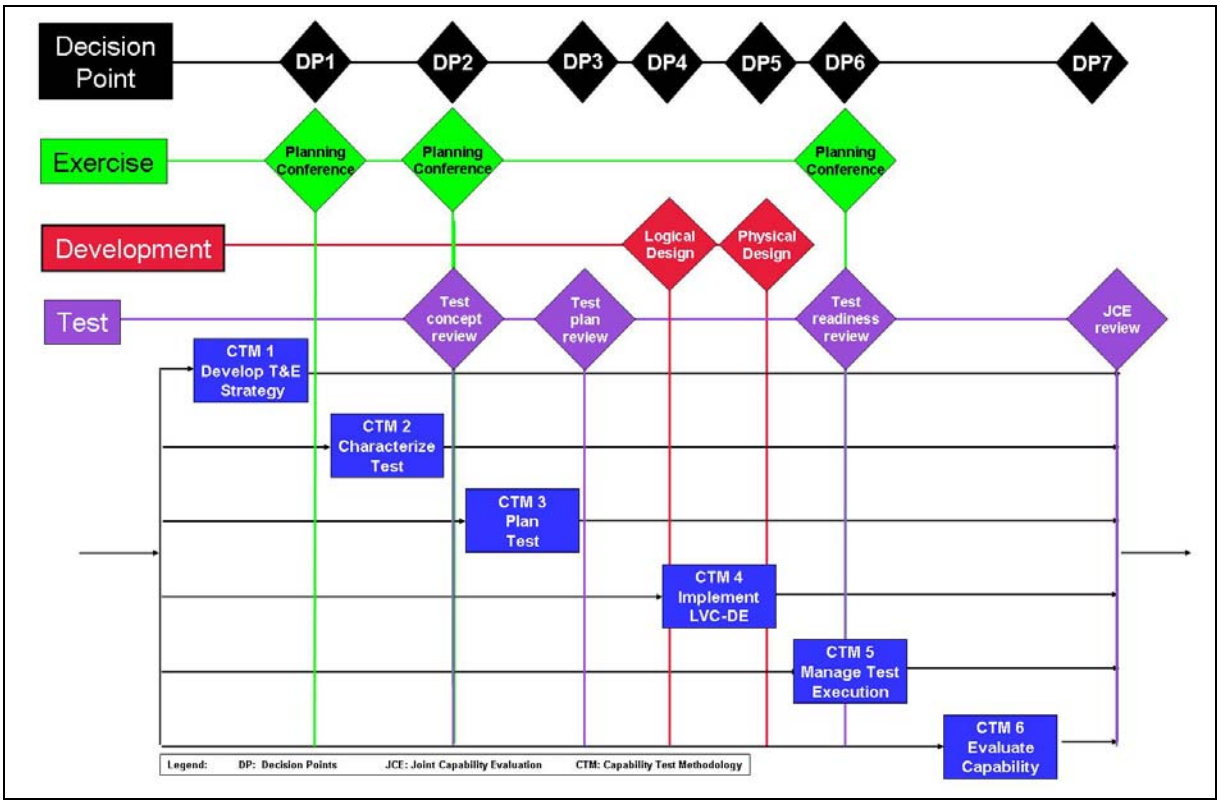

Figure 1-2. CTM Level 1 Steps with Decision Points and Planning Conferences

Each step in the CTM process is composed of multiple levels (processes and sub-processes) that provide, in increasing detail, the inputs, processes, and outputs necessary for the completion of the higher level step or process. The naming convention for these levels begin with level 1, or the overarching view, and continue through levels 2 through 6. The six steps of the CTM process are defined at level 1. Each subsequent level contains additional detail to complete the higher level's function. This multi-tiered layout provides a means to identify a specific process and determine the necessary inputs, actions, and outputs.

Figure 1-3 depicts the overall methodology process structure with process and information flow for the first two levels of the six CTM steps. The boxes shown with dark blue backgrounds are the analyst-focused level 2 processes that make up the evaluation thread.

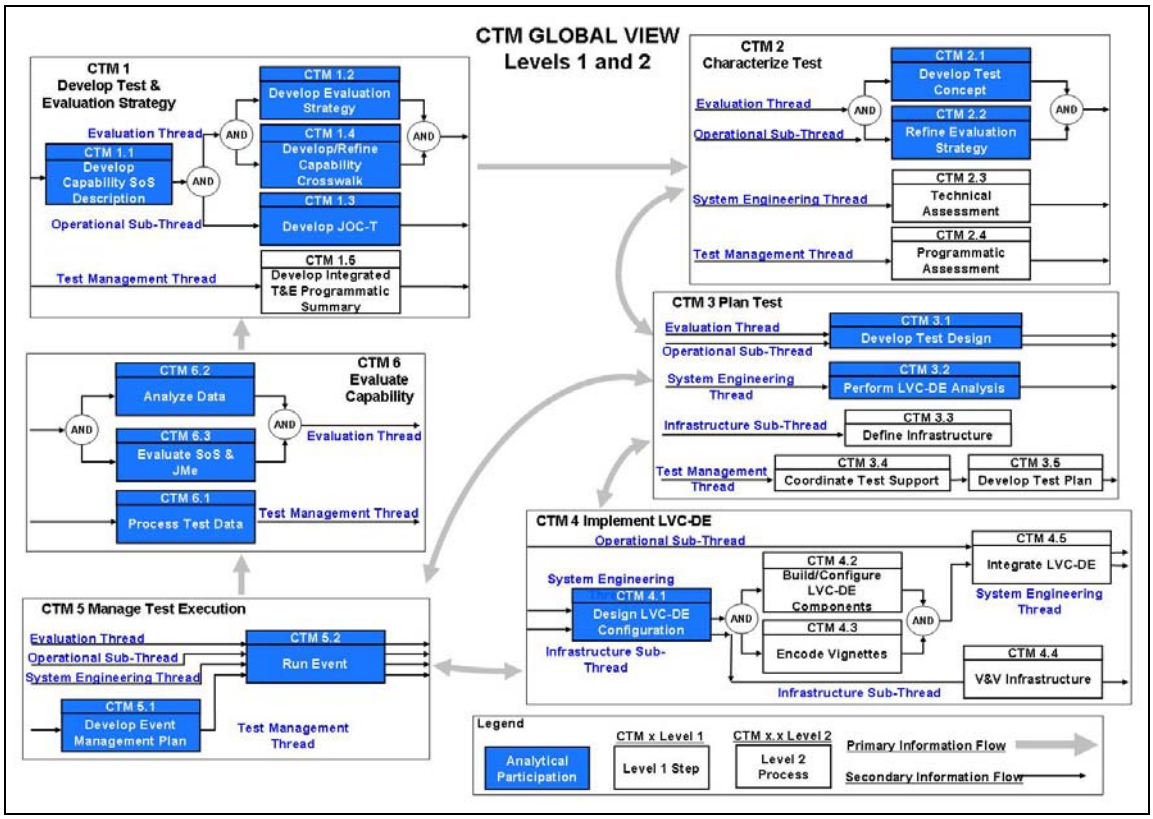

Figure 1-3. CTM Evaluation Thread Level 2 Processes

Many of the level 1 steps and lower level processes are iterative in nature. Numerous processes are performed in parallel, and the results of these processes are fed back into the iterative work of other processes. The following paragraphs briefly describe each of those six primary processes (level 1 steps). In Figure 1-3, the blue blocks indicate processes that require analytical interaction.

1.2.2 Capability Test Methodology (CTM) Steps

CTM Step 1 (CTM 1) Develop Test and Evaluation Strategy. CTM 1 is designed to develop a capability level TES. The TES identifies and describes the capability, SoS, and systems to be evaluated; captures the joint operational context within which the capability will be evaluated; develops the evaluation strategy; and documents the strategy in a structure called the capability crosswalk; and provides the basis for the Test and Evaluation Master Plan (TEMP). Due to the high probability of multi-Service and multi-system contributions to a joint capability solution, the analyst should be prepared to conduct a distributed experiment among multiple locations and across multiple events. CTM 1 is an overarching process which encompasses a strategic view of the actions required for each of the testing sites and agencies involved in the joint event. It establishes many of the fundamental aspects for each of the participating agencies. There are five level 2 processes in CTM 1. Four of these processes are pertinent to the analyst and addressed in Chapter 2: CTM 1.1 Develop Capability/SoS Description, CTM 1.2 Develop Evaluation Strategy, CTM 1.3 Develop JOC-T, and CTM 1.4 Develop/Refine Capability Crosswalk (see Annex E for additional

information on the capability crosswalk). The fifth process, 1.5 Develop Integrated Test and Evaluation Programmatic Summary, is not pertinent to the analyst and therefore not addressed in this handbook. CTM 1.3 is discussed before CTM 1.2 in Chapter 2 due to the need to start developing the JOC-T prior to developing the evaluation strategy.

CTM Step 2 (CTM 2) Characterize Test. The second step in the CTM is to conduct initial planning negotiations concerning test program concepts and test capabilities. Test characterization develops the test concept, refines the TES, and conducts a technical assessment. There are four level 2 processes in CTM 2. Two of these processes are pertinent to the analyst and addressed in Chapter 3 of this handbook: CTM 2.1 Develop Test Concept and CTM 2.2 Refine Evaluation Strategy. The other two processes, CTM 2.3 Programmatic Assessment and CTM 2.4 Technical Assessment fall under the Systems Engineering and Test Management teams respectively, and are addressed in the Action Officer's Handbook.

CTM Step 3 (CTM 3) Plan Test. The third step in the CTM is detailed test planning. Test planning develops the test design, performs LVC-DE analysis, coordinates the required test support, and develops the detailed test plan. There are five level 2 processes in CTM 3. One of these processes, CTM 3.1 Develop Test Design, is pertinent to the analyst and addressed in Chapter 3 of this handbook. The other four processes, CTM 3.2 Perform LVC-DE Analysis, CTM 3.3 Define Infrastructure, CTM 3.4 Coordinate Test Support, and CTM 3.5 Develop Test Plan, are not supported by the analyst and therefore not addressed in this handbook. They are included in the Action Officer's Handbook.

CTM Step 4 (CTM 4) Implement LVC-DE. The fourth CTM step, LVC-DE implementation, concerns technical systems engineering processes for implementing the LVC-DE. These include designing LVC-DE configurations, building and configuring LVC-DE components, encoding vignettes, and the integration of the LVC-DE. The test plan is the major input to this phase. The test plan includes the LVC-DE functional design, vignettes, Data Analysis Plan (DAP), and the test support plan. There are five level 2 processes in CTM 4. One of these processes, CTM 4.1 Design LVC-DE Configuration, is pertinent to the analyst and addressed in Chapter 4 of this handbook. The other four processes, CTM 4.2 Build/Configure LVC-DE Components, CTM 4.3 Encode Vignettes, CTM 4.4 V&V Components & Infrastructure, and CTM 4.5 Integrate LVC-DE, are not supported by the analyst and therefore not addressed in this handbook. They are included in the Action Officer's Handbook.

CTM Step 5 (CTM 5) Manage Test Execution. In CTM 5 Manage Test Execution event iterations are conducted and data are collected. Event-specific schedules are developed during CTM 5.1 and events are run using test plans and JME product inputs as part of CTM 5.2. Event packages and published event schedules feed into the run event process. The phase product outputs are test data and reusable information for other CTM iterations. There are two level 2 processes in CTM 5: CTM 5.1 Develop Event Management Plan and CTM 5.2 Run Event. Chapter 5 addresses both processes, which are supported by the analyst.

CTM Step 6 (CTM 6) Evaluate Capability. The last step in the CTM is the evaluation of the capability. The capability evaluation processes collected data, then analyzes the data with

respect to the test objectives, and evaluates system/SoS performance, task performance, and contributions to JMe. There are three level 2 processes in CTM 6: CTM 6.1 Process Test Data, CTM 6.2 Analyze Data, and CTM 6.3 Evaluate SoS and JMe. Chapter 6 addresses these three processes, which are supported by the analyst.

1.3 Capability Evaluation Metamodel (CEM)

1.3.1 Metamodel

A metamodel is a simple model that approximates the behavior of a large, complex model.[2] Metamodels can be viewed from three different perspectives:

- Set of building blocks and rules used to build models
- Model of a domain of interest
- Instance of another model

1.3.2 Capability Evaluation Metamodel (CEM) Description

A CEM was developed to provide an understanding of terminology and its relationships to the CTM. By using the three different perspectives, the CEM provides an underlying structure for CTM evaluation methods and processes, for example, CTM evaluation-related template content and relationships. The CTM provides business rule relationships for the CTM evaluation thread which is covered in section 1.4. Some benefits of an integrated CEM include:

- Stable structure across DoD programs
- Consistency in DoD inputs to the CTM
- A relational structure of terminology
- A capability evaluation process
- Aids in identifying gaps in processes and methodology

The CEM can be viewed as a set of building blocks and rules that provide the structure and framework for the underlying model. CEM purpose structures CTM evaluation methods and processes and provides basic business rules for the CTM evaluation thread. Similar to the DoDAF, the CEM is derived from multiple sources to provide additional terms and refined definitions. Figure 1-4 shows the key nodes of the CEM and related arcs that support CTM development.

[2] Davis, Paul K., and Bigelow, James H., Motivated Metamodels, Synthesis of Cause-Effect Reasoning and Statistical Metamodeling, RAND, 2003.

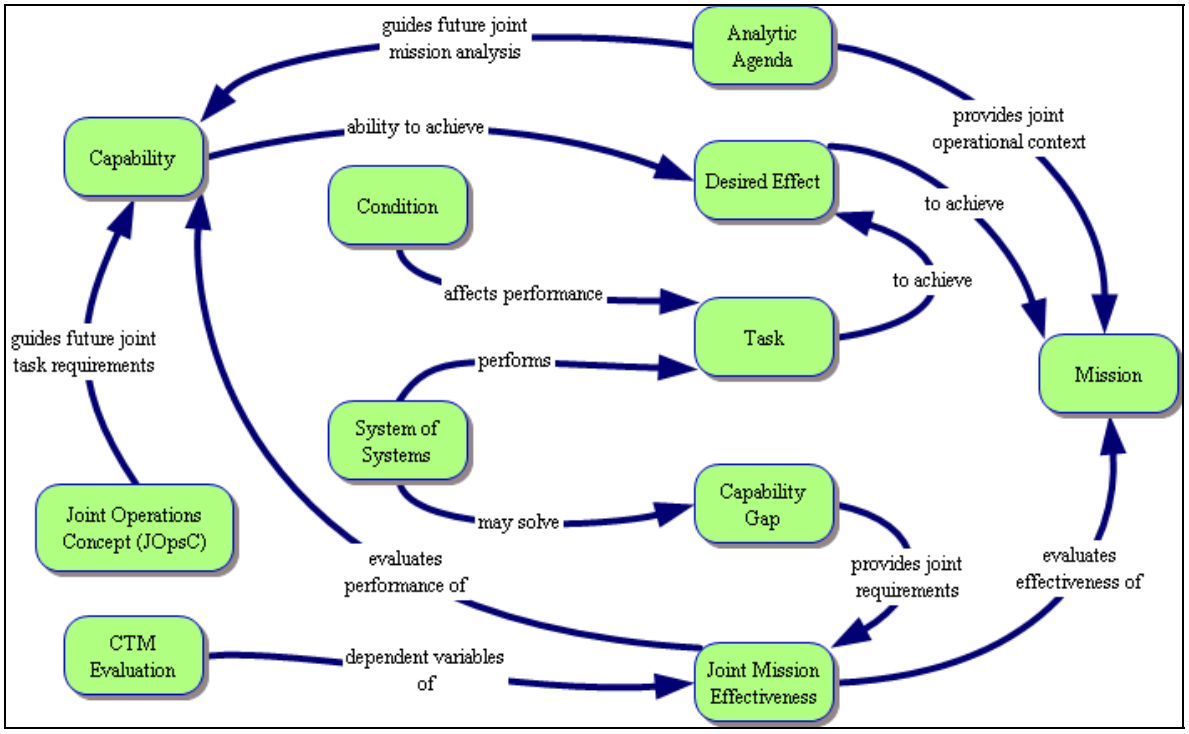

Figure 1-4. Capability Evaluation Metamodel (CEM)

The CEM, also known as the Star Model, provides significant input into the conceptual framework that underpins the analytical thread within the CTM. The CEM enables a clear understanding of the relationships among JTEM lexicon including capabilities, JME, JMe, and SoS. The CEM is a result of extensive research to develop the definitions and interactions. Figure 1-5 provides a high-level view of the CEM six-axis model.

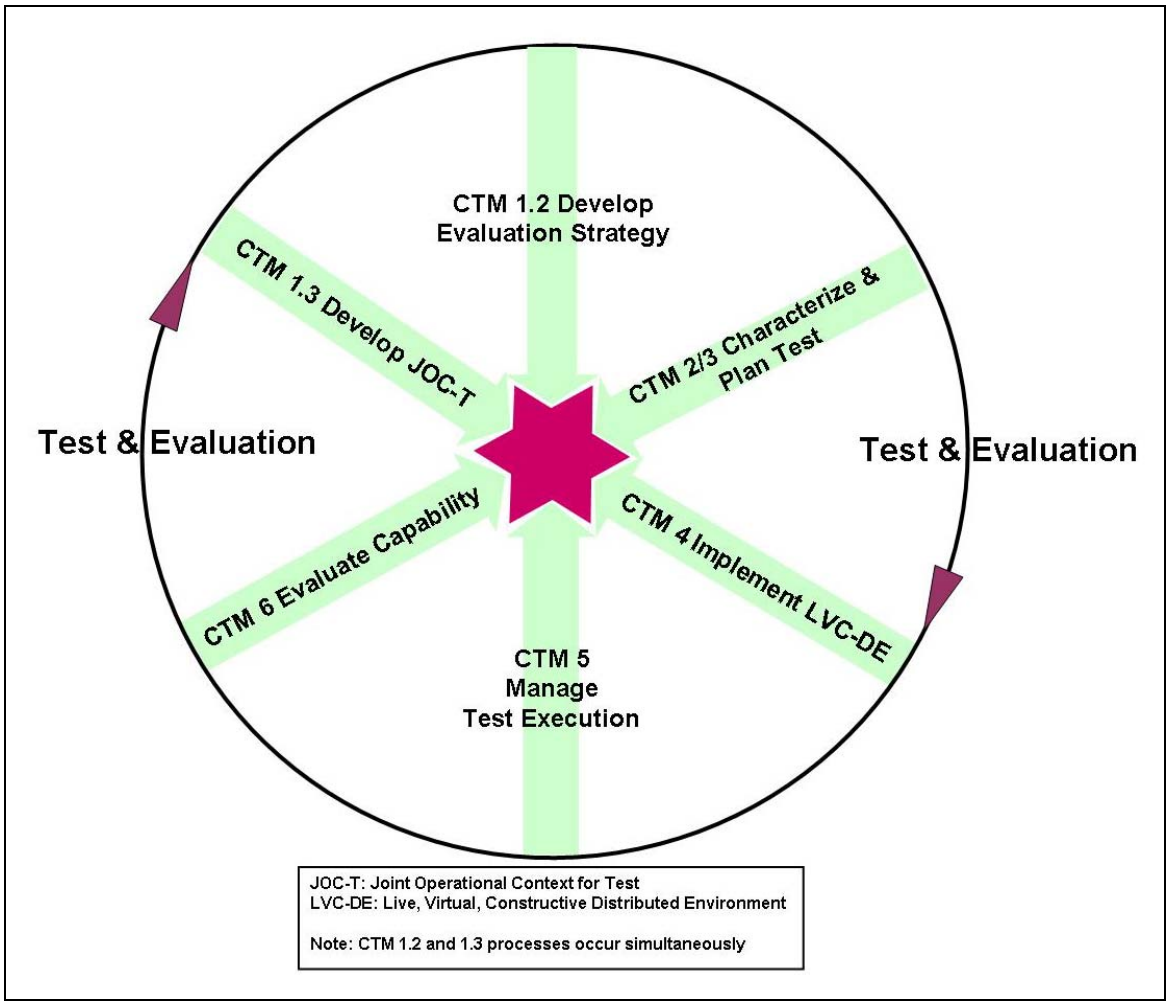

Figure 1-5. Capability Evaluation Metamodel (CEM) Axes

The CEM is designed to assist in developing and evaluating methods and processes used to conduct testing in a realistic JME across the acquisition life cycle to improve the program manager's (PM) ability to deliver joint capabilities to the warfighter. The need for the CEM stems from the JCIDS process.[3] JCIDS is transforming the way the DoD is acquiring new systems and capabilities.

1.3.2.1 CEM Axes

The following paragraphs describe each axis to the CEM:

[3] CJCSI 3170.01G, Joint Capabilities Integration and Development System, 1 March 2009

Joint Operational Context for Test (JOC-T). The JOC-T uses the various authoritative sources to develop description areas for capabilities, which define the operational organizations, resources, missions, environment, and threats that interact with the SoS. Developing the JOC-T includes performing operational and systems analyses to define the relevant set of operational and systems elements and interactions for capability tests. This process will identify source documents and organizations for development of the TEMP. During JCIDS, capability gaps are identified in the achievement of mission-desired effects and in the performance of essential tasks. Figure 1-6 shows the CEM representation of JOC-T development. Chapter 2 provides details of this process.

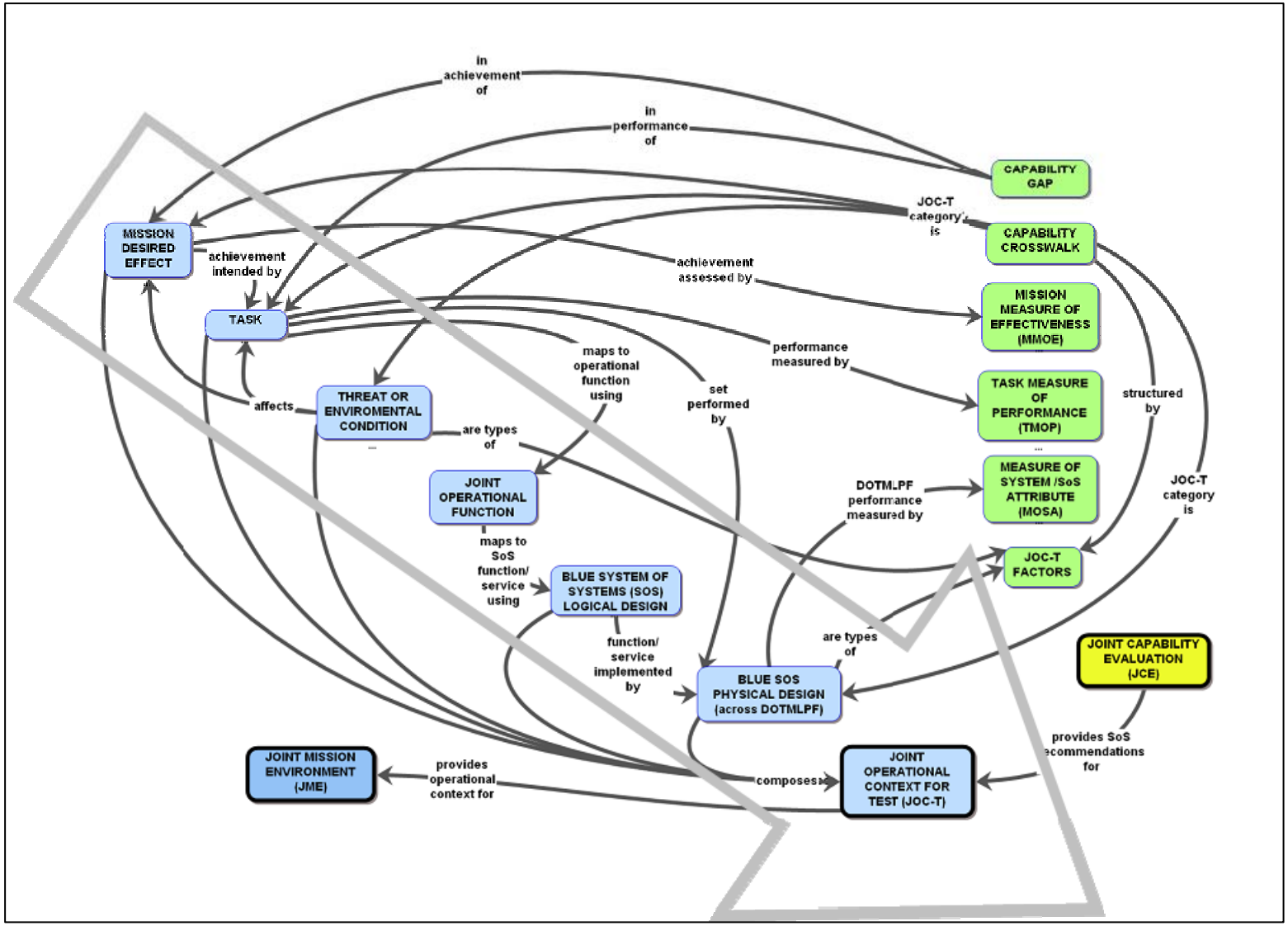

Figure 1-6. JOC-T Axis of the CEM

Develop Evaluation Strategy. The development of the evaluation strategy uses the JOC-T and JCIDS products to describe the capability gap, the SoS solution, the mission, joint tasks, capability and operational issues, and test factors. CEM independent variables are manipulated factors in the test whose presence or degree affects change in dependent variables. There are three independent variable treatment dimensions in a CEM test design: joint mission(s) and task(s); threat and environmental conditions; and SoS configuration options across DOTMLPF resources. CEM dependent variables are response measures, whose changes are caused by the presence, or degree of, independent variables in the test. Dependent variables are measured for increases and decreases in mission effectiveness across a set of test trials. There are three levels of response measures: mission measures of effectiveness (Mission MOE), task measure of performance (Task MOP), and measures of system/SoS attributes (MOSA). Figure 1-7 shows the CEM representation of evaluation strategy development. Chapter 2 provides details of this process.

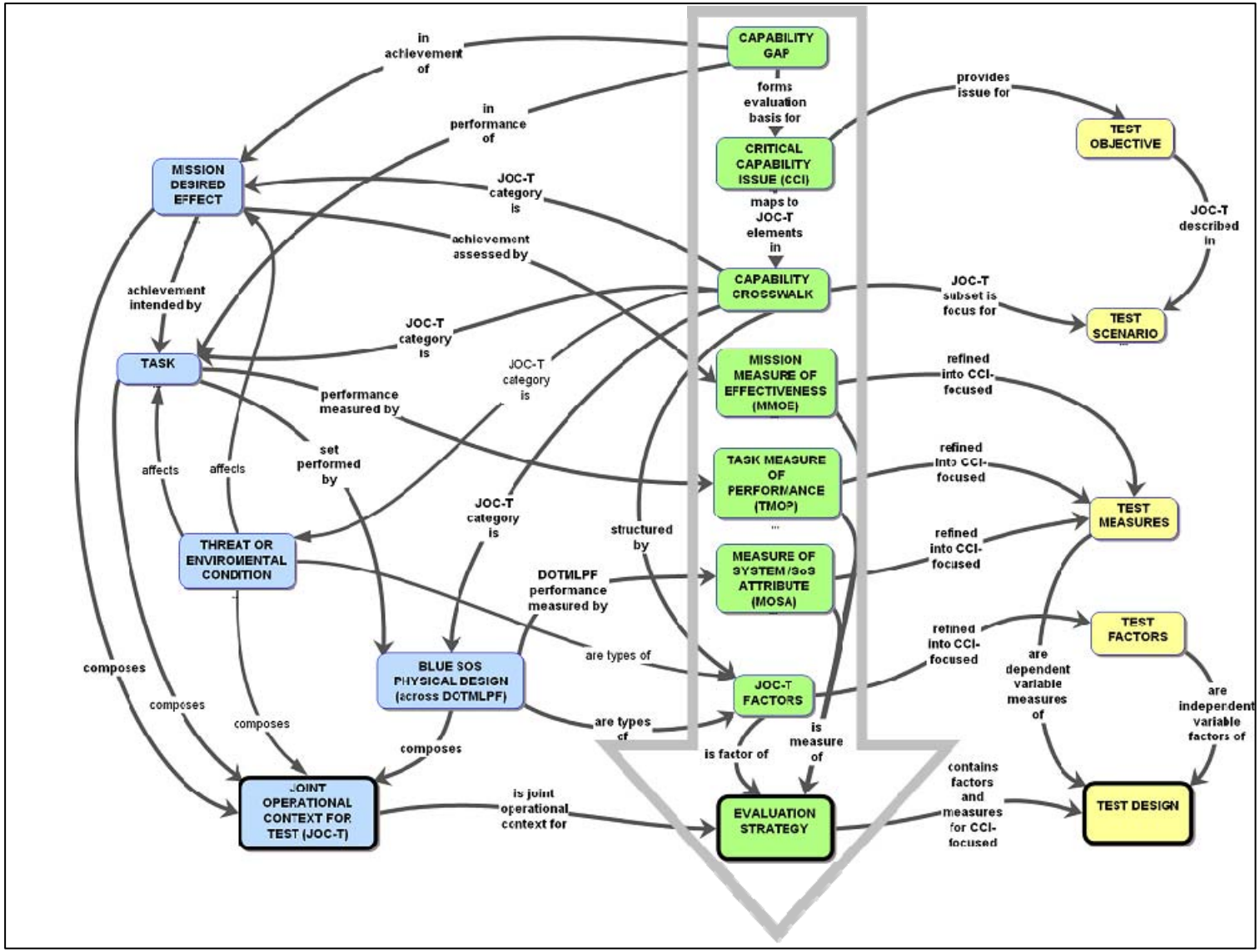

Figure 1-7. Develop Evaluation Strategy Axis of the CEM

Characterize and Plan Test. The characterize and plan test axis is shown in Figure 1-8. This axis focuses on the development of an individual test event. In the characterize test step, a test approach is developed which includes a test goal, test objectives, and test scenario. The plan test step continues with a refinement of the evaluation strategy, the development of an experimental test design to include identification of a test trial matrix and test vignettes. Chapter 3 provides details of these processes.

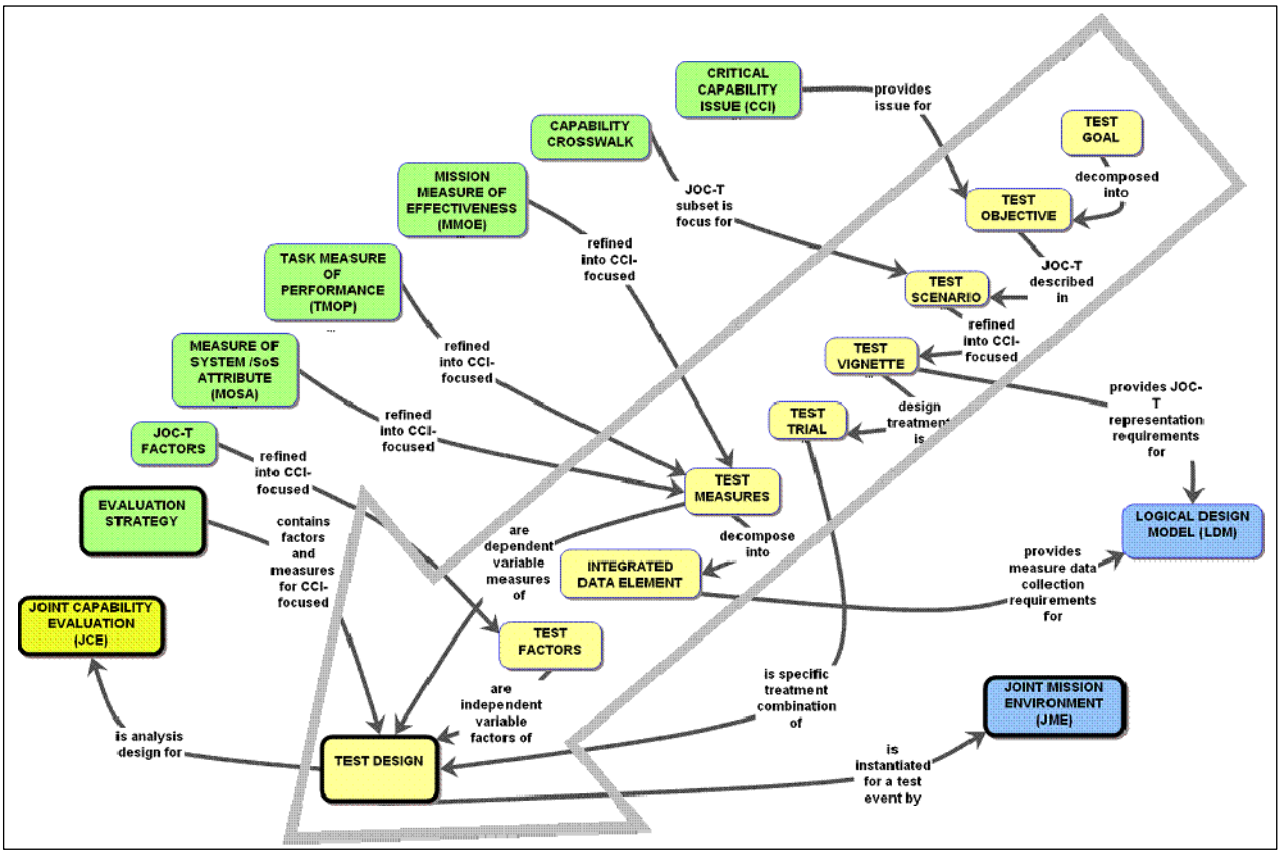

Figure 1-8. Characterize and Plan Test Axis of the CEM

Implement LVC-DE. Figure 1-9 shows the implement LVC-DE axis. This axis focuses on instantiating the evaluation framework, the JOC-T, and the test design into a test event logical and physical design. The resulting JME can then be executed in the follow-on axis. Chapter 4 describes these processes.

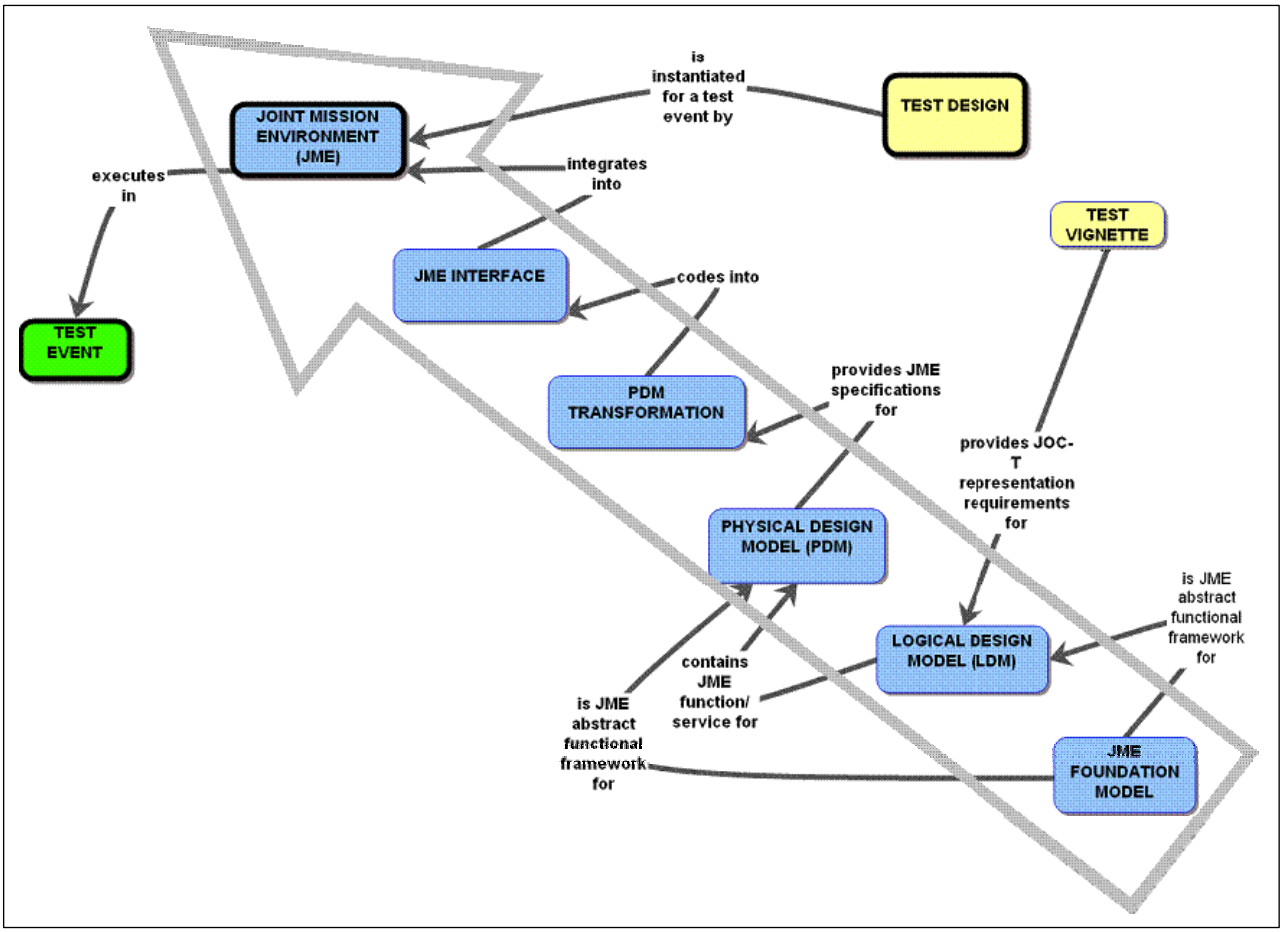

Figure 1-9. Implement LVC-DE Axis of the CEM

Manage Test Execution. The manage test execution axis is shown in Figure 1-10. This axis focuses on the final preparation of the test event to include development of the Data Collection Plan (DCP), conduct of event spirals, and actual execution that results in test data. The data must be verified and validated immediately to ensure the test event provides the correct data which will be used for analysis in the following step. Chapter 5 describes these processes.

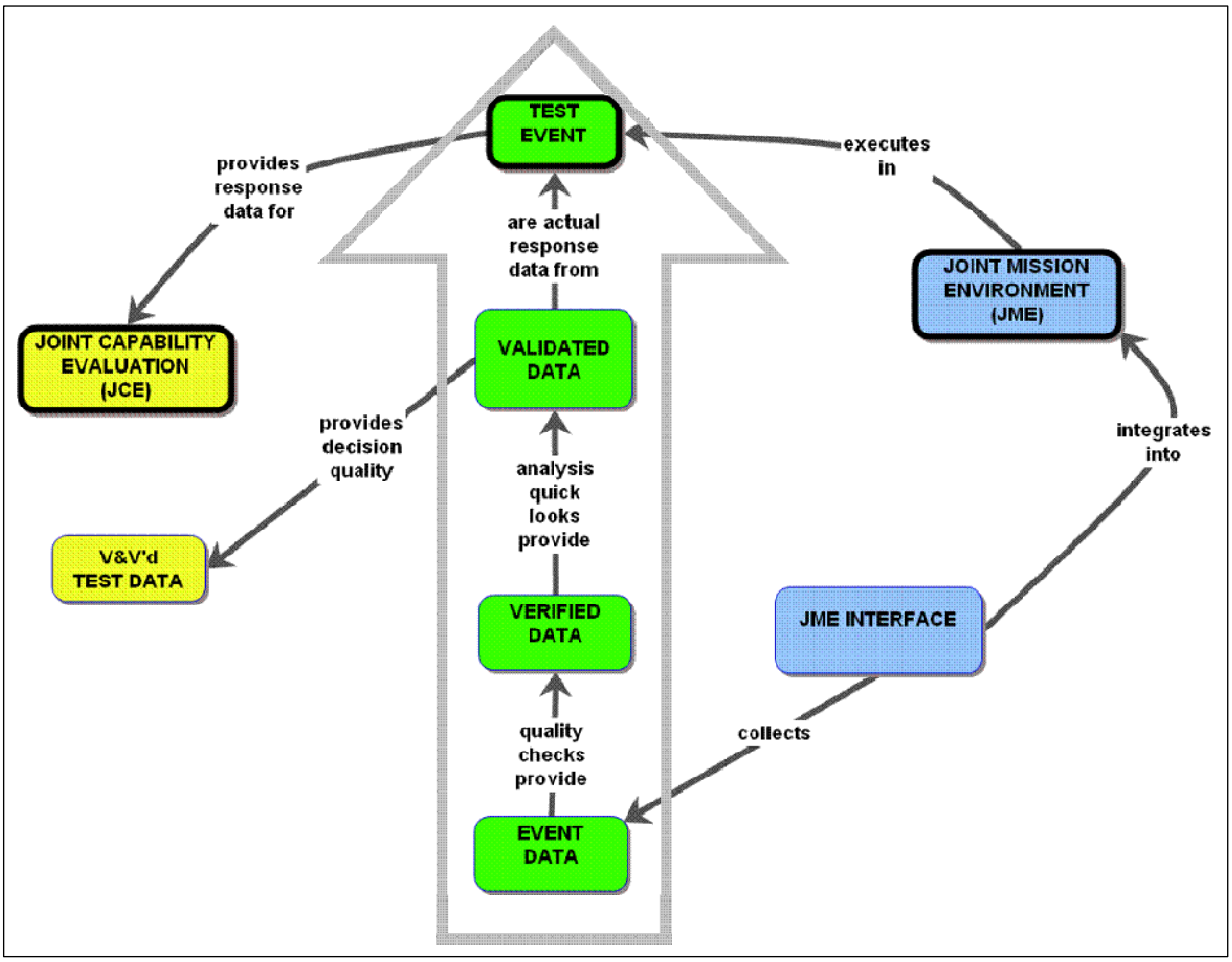

Figure 1-10. Manage Test Execution Axis of the CEM

Evaluate Capability. The evaluate capability axis is shown in Figure 1-11. This axis focuses on the post-test evaluation processes to evaluate:

- System effectiveness, suitability, and survivability
- SoS performance of joint tasks
- SoS impacts on JMe

The evaluation uses the response data from the test event to provide SoS recommendations based on the analysis design produced by the capability test design. The ultimate utility of any SoS is evaluated through the connection of achieving the mission-desired effect. Chapter 6 describes these processes.

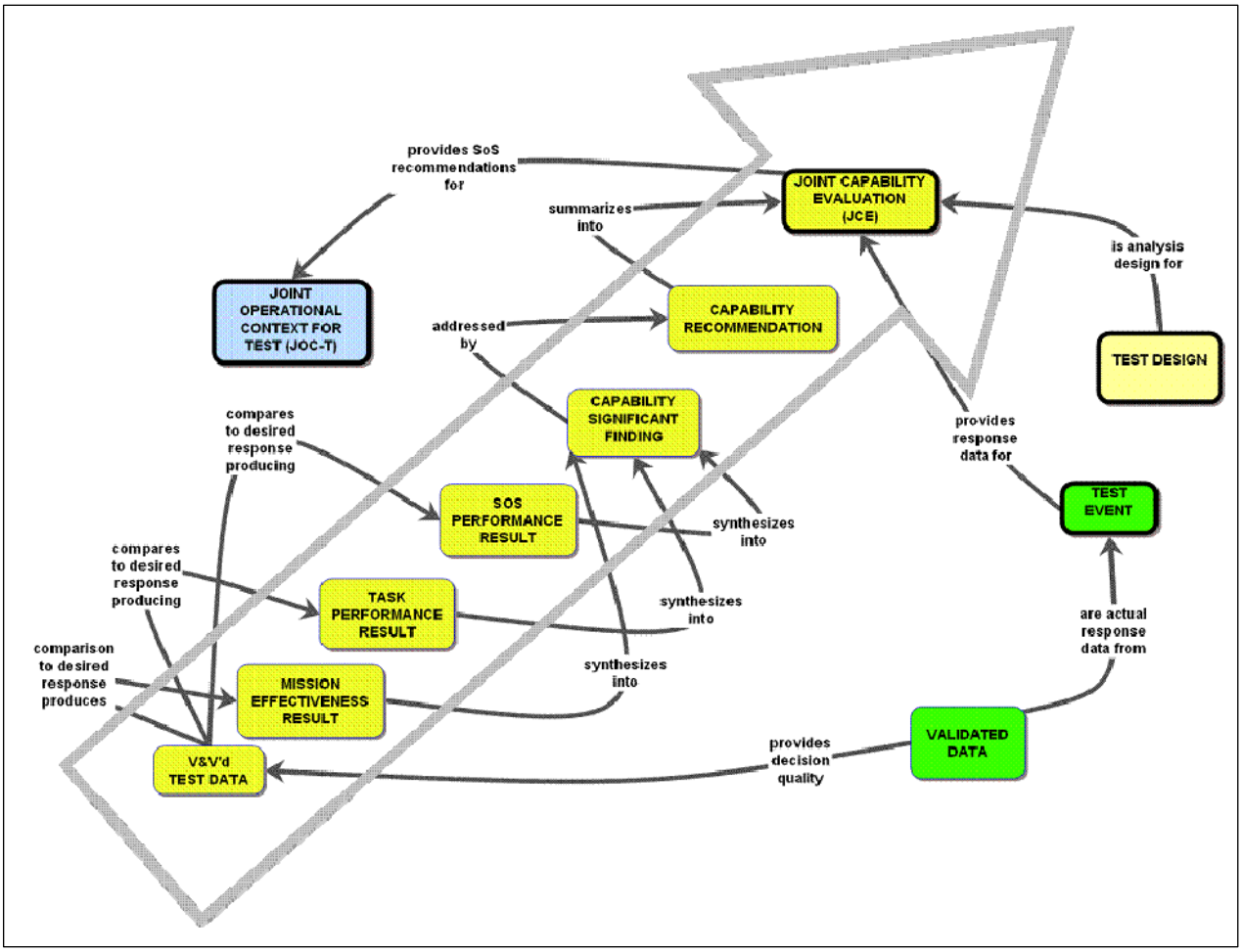

Figure 1-11. Evaluate Capability Axis of the CEM

1.3.2.2 Complete CEM

Figure 1-12 shows the complete CEM with all six axes. The inter-connectivity goes across the different axes. Although this initially appears to be complex, the interactions aid in understanding the overall CTM. This handbook refers to the different CEM axes in the following chapters.

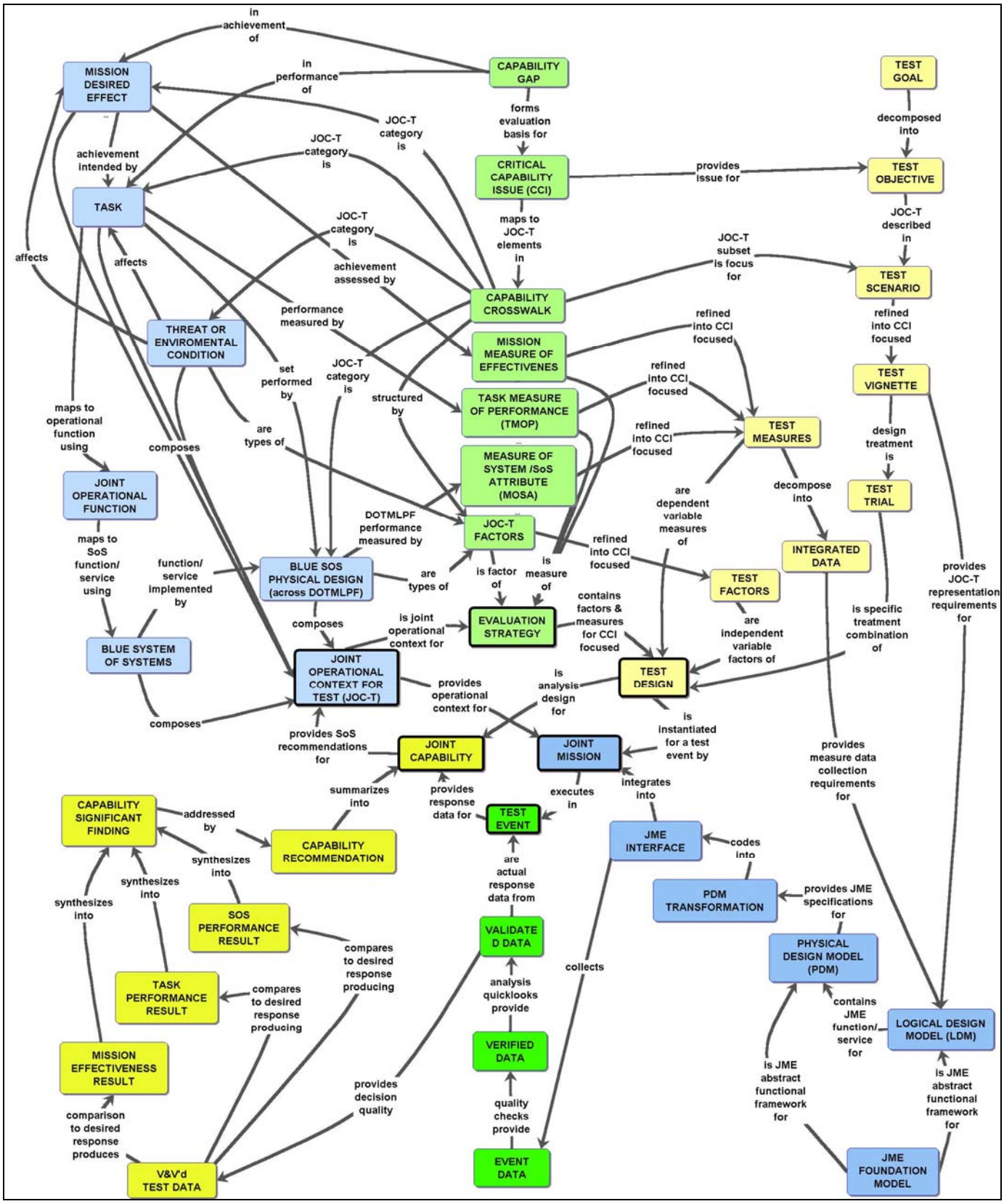

Figure 1-12. Complete CEM

1.4 CTM Evaluation Thread Overview

The CTM evaluation thread is a functional grouping of activities in the CTM. These activities concentrate on the analytical aspects of the T&E. There is an operational sub-thread to the evaluation thread. The other CTM threads are the systems engineering thread and the test management thread.

1.4.1 Methodology Modeling

Critical to any methodology is the understanding of the processes and lexicon which define the mechanisms that result in the accomplishment of the joint mission. Several models have been developed in the JTEM JT&E. These describe the methodology and its relationships to other programs.

The CTM is an integral part of the Defense Acquisition System. It supports acquisition processes including capability assessments, systems development, and defining associated investment plans as the basis for aligning resources. The CTM is intended to operate concurrently with interrelated business practices to include DoD joint capability development and acquisition programs.

1.4.2 Analytical Metamodel-Test-Metamodel (MTM)

An analytical metamodel-test-metamodel (MTM) is proposed to support the CTM and provide an evaluation methodology. This MTM supports determining:

- System effectiveness, suitability, and survivability
- SoS performance of joint tasks
- SoS impacts on JMe

The MTM is a high-level model formulated before and after the test. A framework of test requirements and design is formulated before the test, conducted during the test, and then evaluated following the test. This analytical MTM is infused in all parts of the CTM. Figure 1-13 demonstrates that the CEM and the MTM provide the framework that enables the methods and processes in the CTM. The first step in the analytical MTM is the development of a TES, which generates a test space. This test space will describe the dependent and independent variables of the test to establish the test requirements. The next step refines the test space as a sub-set of the overall test space or through modeling and simulation (M&S) that identifies critical test factors. Resources are then assigned to conduct the test and collect the required data. The test is performed across an LVC-DE. The results are evaluated and determined sufficient or insufficient to meet the capability test requirements. The process is repeated as necessary to complete the T&E of the joint capability. Throughout the entire process, M&S enables the analytical MTM to carry out the methods and processes in the CTM.

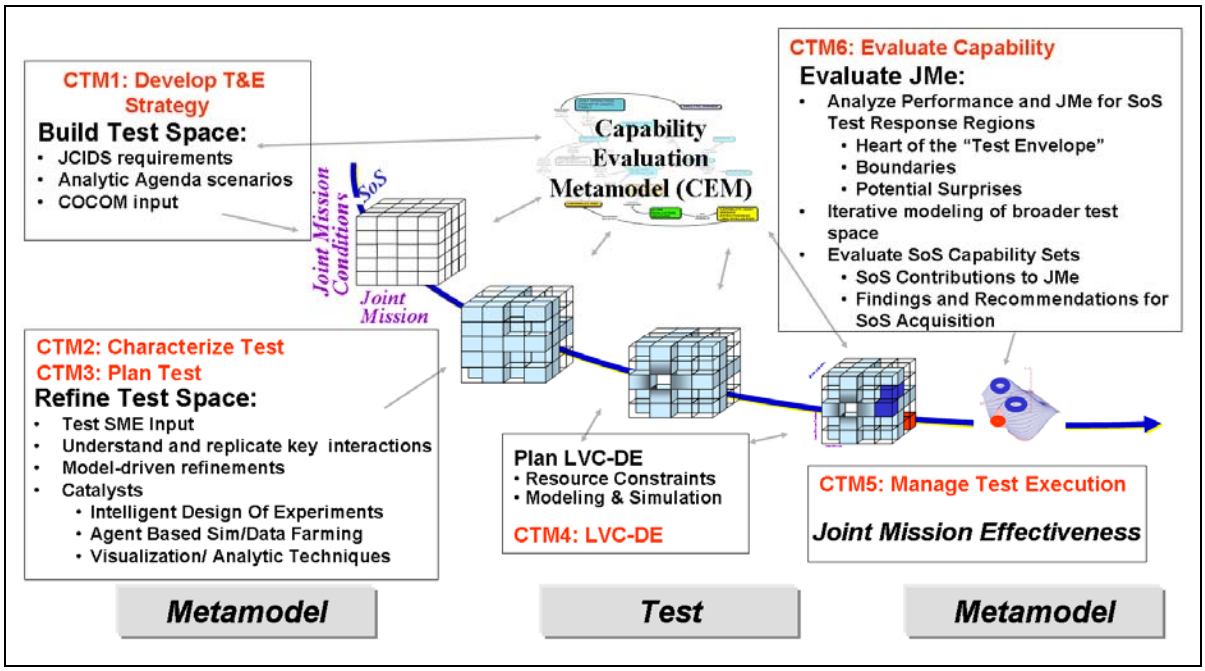

Figure 1-13. Analytical Metamodel-Test-Metamodel (MTM)

1.4.3 Lexicon

The lexicon defines the terms and relationships of the methodology. A DoD capability is defined as the ability to achieve a desired effect under specified standards and conditions through combinations of means and ways across doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) to perform a set of tasks to execute a specified course of action.[4] A desired effect represents a condition for achieving an associated strategic or operational objective.[5] A task or set of tasks is an action or activity (derived from an analysis of the mission and concept of operations) assigned to an individual or organization to provide a capability.[6] It may be referred to as a discrete action or set of actions that enables a mission or function to be accomplished. The means and ways are the systems that interact to form a SoS and employed in a manner to execute a specified course of action. The means and ways include materiel and non-materiel attributes which must be considered across DOTMLPF. These definitions construct the framework that joint capabilities provide the means and ways to perform a set of tasks in order to achieve the set of desired effects that lead to mission success (as shown in Figure 1-14). This paradigm is the key to understanding the metrics used to evaluate system performance, SoS performance, and mission effectiveness.

[4] CJCSI 3170.01G, Joint Capabilities Integration and Development System, 1 March 2009.

[5] U.S. Joint Forces Command (USJFCOM), Commanders Handbook for an Effects-Based Approach to Joint Operations, 2006.

[6] CJCSM 3500.04E Universal Joint Task List (UJTL) Manual, version of August 1, 2005, updated until 25 Aug 08.

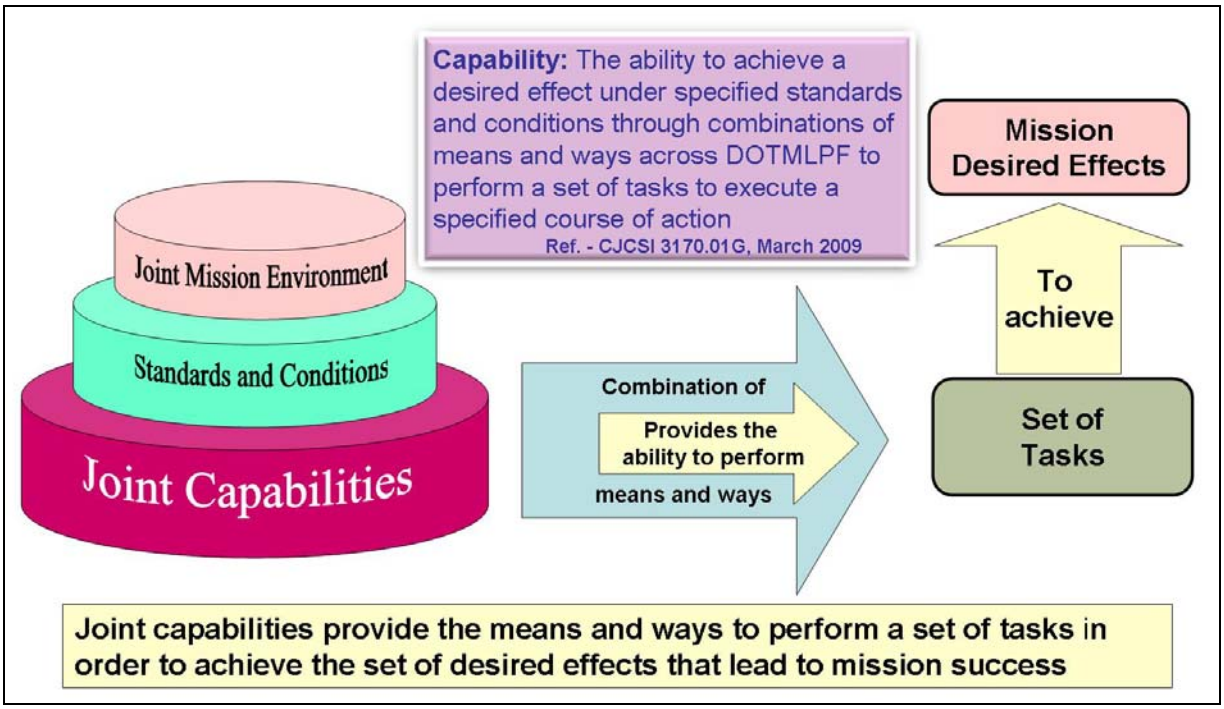

Figure 1-14. Joint Capability Definition

The definition and use of the term "effect" and its associated measures of effectiveness (MOE) are not agreed upon or understood.[7] Frequently an analyst uses MOEs instead of measures of performance (MOP), or vice versa. Desired effects tend to be results oriented and considered at a mission level. This implies that MOEs exist as a primary means of measuring mission effectiveness, whereas MOPs tend to measure task performance.

Another metric used in the T&E community is key performance parameter (KPP). KPPs are attributes or characteristics of a system considered critical or essential to the development of an effective military capability and those attributes that make a significant contribution to the key characteristics as defined in a joint operational concept. While KPPs apply to systems, they also apply to a more complex SoS that makes up a joint capability.

An SoS is a set or arrangement of interdependent systems that are related or connected to provide a given capability (Figure 1-15). The loss of any part of the system will significantly degrade the performance or capabilities of the whole. The SoS must be described in terms of materiel and non-materiel interaction attributes that are in categories of DOTMLPF.

[7] Lindsey, Scott, How to Write an Effect, Naval Proceedings, April, 2006.

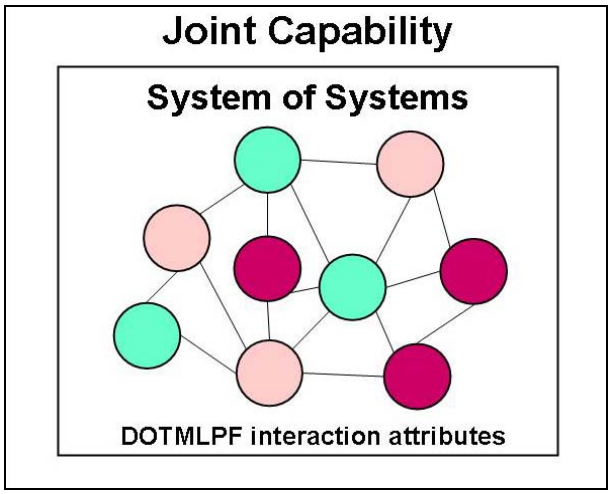

Figure 1-15. System of Systems (SoS)

Desired effects and MOEs are the means to evaluate JMe. Task accomplishment is completed by joint capabilities and measured by MOPs. Joint capabilities are described by SoS and performance measured by KPPs. It would simplify the evaluation process if SoS performance was an indication of task accomplishment and an indication of the achievement of desired effects. Although a direct correlation exists between metrics, it cannot be assumed that they are the only variables which affect performance and effectiveness. Task performance may be a function of SoS performance plus some value *K* that makes up the conditions and standards that surround the task(s). Likewise, mission effectiveness may be a function of task performance plus some value *J* that makes up the conditions and standards that surround the mission. Because linearity of the measures is not known, all levels of performance (SoS performance, task accomplishment, and mission effectiveness) must be evaluated in joint testing.

1.4.4 Define the Test Space

As proposed earlier, JMe can be measured by desired effects and MOEs. The factors that could make up the independent variables in the evaluation process (referred to above as the value *K*) should be described. The JMe is a function of joint capabilities or friendly SoS, the JME, and the defined joint mission (JM).

$$JMe = f(SoS, JME, JM) \qquad (1)$$

The JME conditions include the disparate forces, neutral parties, geographical, and meteorological conditions, to name a few. The JM is the joint task(s) to be performed along with a purpose (see definition of mission in Annex L). The JM purpose is described in terms of objectives, end states, and desired effects. To test joint capabilities in a JME, the functional definition in equation (1) will provide the building blocks for the design of the test space. The test space design is part of the first metamodel in the MTM; it is developed as part of CTM 1 and CTM 2 (refer to Figure 1-13). As illustrated in Figure 1-16, the test space is a set of tuples or three-dimensional cubes, and SoS, JME, and JM are primary axes. In reality, each axis will have numerous dimensions constructed of factors or attributes that

affect JMe. For example, consider the SoS under test having three attributes that would be factors in the test (stand-off distance, accuracy, and lethality). Also assume for this example, the JME must consider four conditions as part of the test (mobility of enemy targets, stealthiness of enemy targets, weather conditions, and terrain). The third axis in the example will assume the JM as one additional factor with two different JM values (time sensitive targeting and close air support). In totality, the test space in the example would be in ten-dimensional space (5+4+1). Each factor may be continuous or have numerous discrete values which could require extensive testing resources to evaluate adequately SoS performance and mission effectiveness.

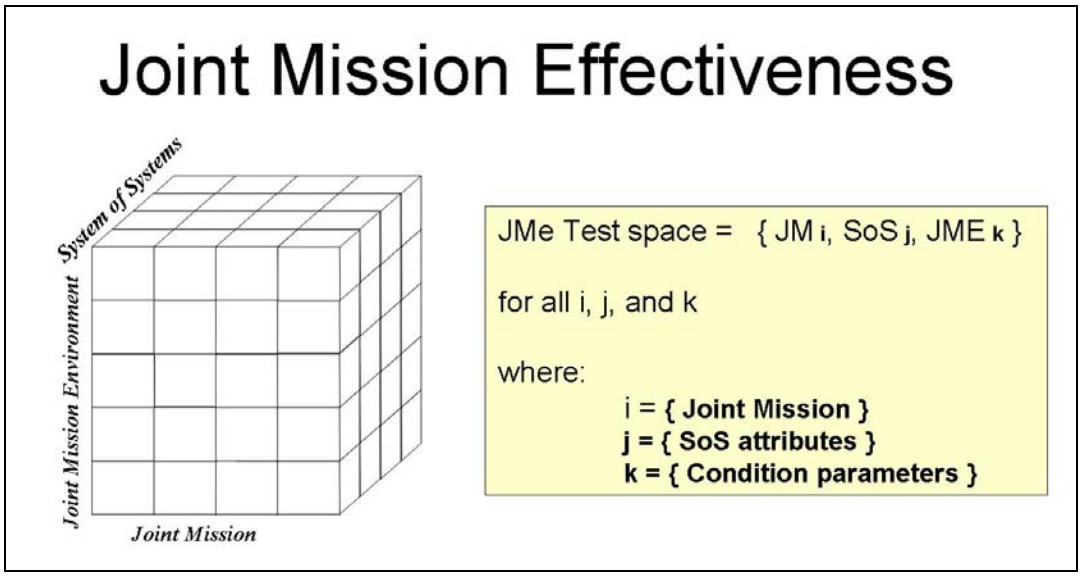

Figure 1-16. JMe Test Space

A critical step in defining the test space is determining the set of factors to consider in the test. Historically, T&E analysts developed dendrites of the system under test (SUT) to capture critical operational issues (COI) from combat developers or other operational or community of interest sources, and determined the associated metrics and data elements for collection. This is typically an iterative process of analysts working with systems engineers and PMs to determine what issues and metrics appear to be of most interest to the program. In a joint test, the JCIDS process and associated documents may provide KPPs and MOEs. Other critical factors may need to be identified through an exploratory analysis process. M&S tools, efficient designs of experiments, and mission analysis models (Mission Means Framework,[8] Activity Based Modeling,[9] and Capabilities Based T&E[10]) may support identifying critical test factors.

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[8] Sheehan, Jack, Missions and Means Framework, Measures and Evaluation Techniques, briefing, 2006.

[9] Ring, S.J., Nicholson, D., Thilenius, J., and Harris, S., An Activity-Based Methodology for Development and Analysis of Integrated DoD Architectures, 2004 Command and Control.

[10] IDA, Capabilities Based T&E, http://www.ida.org/researchareas/resourceandsupportanalyses/training%20readiness%20and%20personnel%20issues.php [Last accessed 28 Jan 2009]

To help define the test space, the analyst should also use the measures framework. The measures framework addresses key components of the joint capability definition; mission desired effects, task performance, and the combination of means and ways. The CTM uses three levels of measures: Mission Measures of Effectiveness (Mission MOE) to evaluate achievement of mission desired effects, Task Measures of Performance (Task MOP) to evaluate task performance, and Measures of Systems/SoS Attributes (MOSA) to evaluate Systems/SoS performance that make up the capability means and ways. At the capability level, the measures framework addresses the fundamental joint capability question or issue, "can the joint SoS perform the tasks under a set of standards and conditions which contribute to mission desired effects". Known as critical capability issues (CCI), the focus of the Mission MOE is on measuring task performance and mission effectiveness. At the component System/SoS level, the Task MOP addresses the ability to perform Service tasks as defined in the COIs. COIs include operational effectiveness and operational suitability issues examined in OT&E to evaluate/assess a system's capability to perform its tasks. Note that performance characteristics exist at both the System and SoS levels. Therefore, MOSA include measuring KPPs, Critical Technical Parameters (CTP), and materiel/non-materiel attributes across DOTMLPF along with measures of performance, measures of effectiveness, and measures of suitability.

1.4.5 Refine the Test Space

The example provided in the previous section consisted of 10 factors that could vary over multiple vignettes and test runs to gather data. Assuming all 10 factors could be quantified and each only had two values (high and low values), there could be 2^k factorial combinations of factors. In this case k =10, thus 2^{10} combinations = 1024. A more realistic joint capability test would probably have two to three times the number of factors. The number of factorial combinations would far exceed testing resources. In terms of the analytical MTM, the test space must be refined so as to focus limited testing resources on the primary factors in the right combinations that allow successful evaluation of a response surface (Figure 1-17). The response surface of the output parameters should be charted and a sensitivity analysis conducted to determine peaks and valleys in the response. Of ultimate interest is to determine the feasible region and provide recommendations on materiel and non-materiel solutions that provide optimum SoS performance.

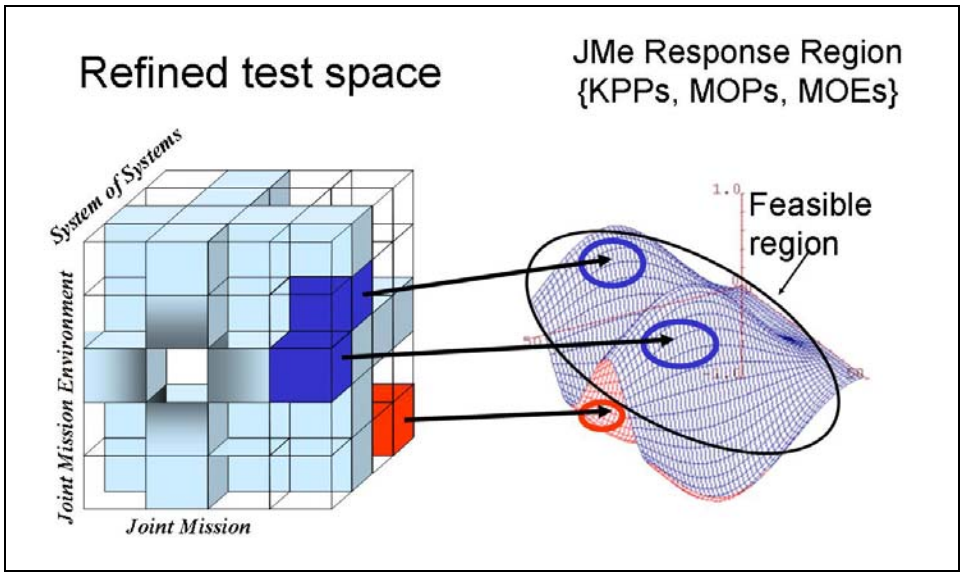


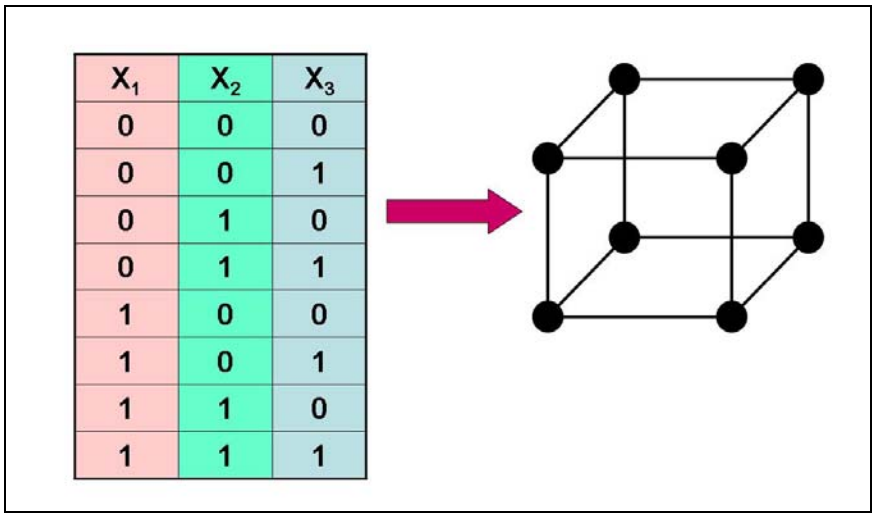
Figure 1-17. Refined Test Space and Response Region

Test design can benefit from DOE research and techniques that are focused on simplifying the required number of trials. Although the use of T&E is not the same as DoD's use of the term "experimentation," the same scientific method can be applied to T&E. It is about cause and effect, to discover the effects of presumed causes.[11]

1.4.6 Refinement through Design of Experiment

So far, examples used are simple 2^k factorial designs (two levels for each factor). Figure 1-18 demonstrates a three-factor table and plot with two levels for each factor. In this 2^3 factorial design, eight trials could be conducted to test each combination of factors to determine the outcomes.

[11] Shadish, W., Cook, T., and Campbell, D., Experimental and Quasi-Experimental Design for Generalized Causal Inference, New York: Houghton Mifflin Co., 2001.



X_1	X_2	X_3
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

Figure 1-18. Three Factor – Two Value Factorial

If each factor had 10 different values, a full factorial analysis would require 10^3 or 1,000 test trials. This is potentially not feasible in a limited resource environment.

Following the idea that simpler is better, analysts should look for ways to design the test that investigates the critical factors of the SoS and provides feasible solutions with minimal test requirements. Test designs that are other than full factorial should provide a reasonable number of trials and possess desired properties of orthogonal, efficient, space filling, and ease of use.[12] Based on the premise that an SoS under a joint test will require a large number of factors as independent variables (>10) and each factor has more than two levels (values), a good general-purpose design for exploring complex simulation models is a Latin Hypercube (LH) design.[13] Random LH designs are sufficient when the number of design points is much larger than the number of factors. Nearly Orthogonal Latin Hypercube (NOLH) designs are more space filling and consistent orthogonal properties when the number of factors is small or moderate.[14] In the prior example of 10 factors with two levels (2^{10} design points), the full factorial design of 1,024 points can be reduced to 33 points with a NOLH design. This represents a significant reduction in test resources needed to evaluate the critical factors for the SoS.

1.4.7 Refinement through Exploratory Analysis

Simulation of complex adaptive systems can support joint T&E of SoS in a JME. Agent Based Modeling and Simulation (ABMS) software tools are able to examine relationships between numerous input variables and output measures. ABMS can be used at the

[12] Kleijnen, J. P. C., S. M. Sanchez, T. W. Lucas, and T. M. Cioppa., A user's guide to the brave new world of simulation experiments, INFORMS Journal on Computing 17 (3): 263-289 (with online companion), 2005.

[13] Sanchez, Work smarter, not harder: Guidelines for designing simulation experiments, Proceedings of the 2006 Winter Simulation Conference, 2006.

[14] Cioppa, T. M., and T. W. Lucas, Efficient nearly orthogonal and space-filling Latin Hypercubes, Technometrics 49(1): 45-55, 2007.

system-level to determine patterns that emerge from rules defined solely at the individual level.[15] ABMS uses agents to represent systems in order to model and simulate decisions and interactions in a complex environment. Three properties to consider in a complex environment that can be modeled by ABMS are:

- Nonlinearity: Not all components (agents) are additive.
- Diversity: Agents are independent and different from each other.
- Aggregation: Agents can be grouped to form a single agent at a higher level.16

The primary advantage of ABMS is that numerous runs can be made over a short period of time with minimal cost to provide some understanding of factor response to the output variables. T. M. Cioppa was able to examine a complex peace-keeping mission environment with 22 variables and 129 different design points using NOLH.[17] Using ABMS, Cioppa ran 100 independent seeded replications to construct a force exchange ratio using 22 variables (factors).

In refining the test space for a joint test, ABMS can be used for exploratory analysis to examine factor response (sensitivity analysis) in order to determine those factors which significantly impact the SoS performance and JMe. Those factors which have little effect on the output variables could be set at fixed values requiring fewer test design points and reduced T&E resources. The idea of "data farming" is being considered as a part of the JTEM methods and processes. Simulating the JME over thousands, or even millions, of replications provide better estimates of factor response in a scenario.[18] Data farming may provide a complete view of possible outcomes to include outliers.

1.5 Summary

The evaluation thread of the CTM is designed to enable effective system testing in a realistic JME and to evaluate system and SoS contributions to JMe. This chapter has provided an overview of the CTM and introduced several models that provided the building blocks for the development of the evaluation thread. The analyst overall objective is to evaluate the systems and system of systems ability to provide a joint capability. The analyst must develop the evaluation strategy and ensure that it is carried out in a manner that will provide sufficient data to provide findings and recommendations to program managers and other decision makers in the acquisition and employment of systems.

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[15] Macal, Charles M. and North, Michael J., Tutorial on Agent-Based Modeling and Simulation Part 2: How to Model with Agents, Proceedings of the 2006 Winter Simulation Conference, IEEE 1-4244-0501-7/06., 2006.

[16] Holland, J. H., Hidden Order: How Adaptation Builds Complexity, Reading, MA, Addison-Wesley, 1995.

[17] Cioppa, T. M., Efficient nearly orthogonal and space filling experimental designs for high-dimensional complex models. Doctoral dissertation, Operations Research Department, Naval Postgraduate School, Monterey, California, 2002.

[18] Horne, Gary E., and Meyer, Ted E., Data Farming: Discovering Surprise, Proceedings of the 2004 Winter Simulation Conference, 2004.

The Analyst's Handbook provides a single source document for test agency analysts and PMs who are participating in joint-level testing. It provides an explanation of the CTM processes, the key inputs and outputs of each, and references to detailed information sources. The overview allows the analyst to determine quickly which chapter to reference for any step or process in the CTM process. The handbook is designed to be a bridge between the T&E analyst and the CTM, which provides the processes and methods for designing and executing tests of SoS in the JME.

Figure 1-19 is a simplified version of the CEM star chart. The axes are labeled with the corresponding chapters that apply to each axis. This chart may be used as a navigation tool for this handbook which follows through the evaluation thread processes.

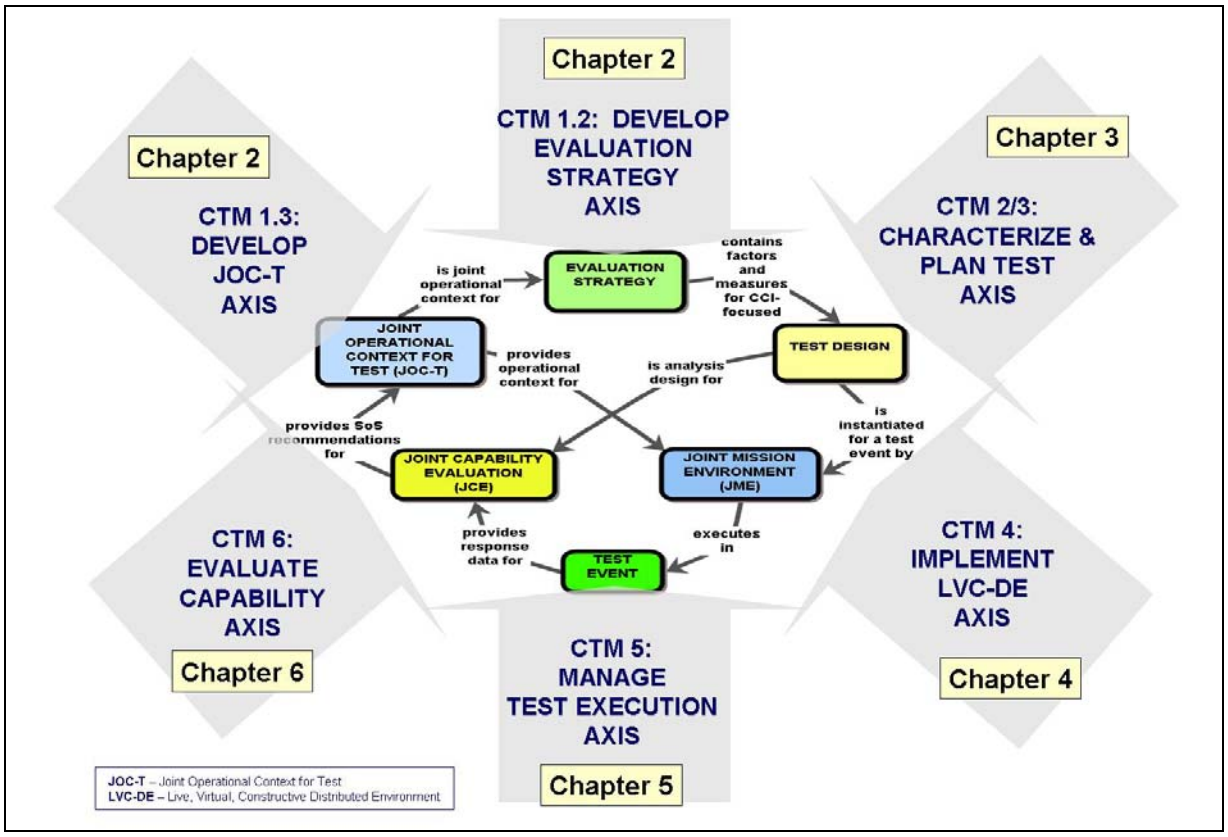

Figure 1-19. CEM Navigation Chart

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2
DEVELOP TEST & EVALUATION STRATEGY

This chapter describes the methods and processes the analyst uses to carry out the evaluation thread of the CTM. It focuses on developing an overall evaluation strategy for the capability under test. This chapter addresses the evaluation thread for CTM 1 Develop Evaluation Strategy. Section 2.1 provides a description of this step and the processes that are part of the evaluation thread. Detailed instructions to guide the analyst in conducting the evaluation methods and processes are provided in the chapter.

2.1 Capability Test Methodology (CTM) and Processes for CTM 1

The first step in the CTM is to develop the overall TES for the capability under test. It is a critical process that has a tremendous effect on the remainder of the methodology. The analysis team will examine relevant documentation and gather stakeholder input to develop the evaluation framework by identifying the most important factors and the measure framework used to assess capability performance. The team may use the evaluation framework to conduct an iterative exploratory analysis that examines the possible factors and their effects on the measures of interest. The use of exploratory analysis is optional; it should help the team identify the most important factors for examination during subsequent test events. TES development identifies and describes the capabilities and SoS to be evaluated, captures the joint operational context within which the capabilities will be evaluated, develops the evaluation strategy, and documents the strategy in a structure called the capabilities crosswalk. This chapter discusses a single iteration of the development process. As capability testing proceeds, the evaluation may require the analyst to revisit CTM 1 to update the strategy to reflect any findings that impact the analytical requirements. Figure 2-1 shows four processes under CTM 1 that are important to the analyst: 1.1 Develop Capability/SoS Description, 1.2 Develop Evaluation Strategy, 1.3 Develop JOC-T, and 1.4 Develop/Refine Capability Crosswalk. These processes (and their sub-processes) will be the focus of discussion in this chapter. Three of the four processes (1.2, 1.3, and 1.4) can occur in parallel.

The primary output of this process is an objective evaluation of the SoS or SUT in terms of its contribution to delivering the intended capability and contributions to JMe. All the previous processes lead to this ultimate goal. This evaluation is used by decision-makers to determine the future of those systems: to field them as-is, to return them to PMs and developers for further work, or to cancel those programs in favor of others that are more promising. The PM should select systems that not only meet the KPP and key system attribute (KSA) as outlined in JCIDS documents (Capability Development Document [CDD] and Capability Production Document [CPD]), but also demonstrate beneficial and cost-effective impacts on mission effectiveness in the SoS's operational context.

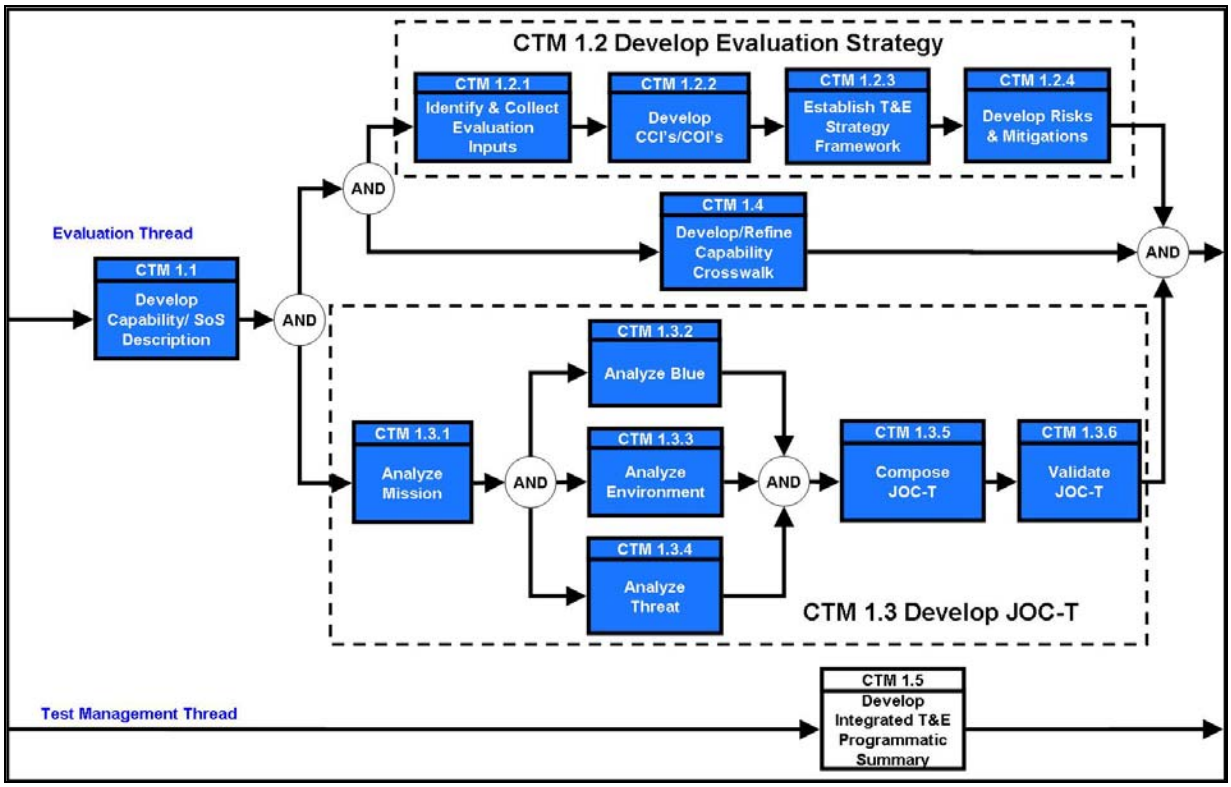

Figure 2-1. CTM 1 Develop Test & Evaluation Strategy

CTM 1.1 *Develop Capability/SoS Description.* This process explains the capability to be tested and describes the SoS involved in the test program. It provides an initial description of the mission objectives and depicts the high-level mission concept. The process takes into account the initial documents such as the individual system test plans, JCIDS documents, and the approved analysis of alternatives (AoA) plans. Using these documents, the initial system description and SoS description are developed to describe the key features and subsystems, and hardware and software, for each increment's configuration. The joint capability areas (JCA), analytical baselines, and the Universal Joint Task List (UJTL) are also reviewed as references for the SoS and the SUT.

An SoS is a set or arrangement of interdependent systems that are related or connected to provide a given capability. The loss of any part of the system will significantly degrade the performance or capabilities of the whole. To describe fully the capability, the SoS must be decomposed into testable systems that can be integrated into the JME. SoS attribute areas may also be identified from capability gaps and key characteristics. It is possible to map these attributes to the mission areas across the materiel and non-materiel DOTMLPF elements. Since the SoS attribute areas are required to have associated performance measures, this mapping system ties the individual systems to SoS mission areas and to measurable and testable SoS attributes.

This process is a primary input into the development of the evaluation strategy, which initiates the evaluation thread of the CTM. Analyst participation should occur during this process to understand the SoS that will be tested to include key attributes and test factors that will play a role in the test design. CTM 1.1 has no sub-processes.

CTM 1.2 *Develop Evaluation Strategy.* In this process, different sources provide input into the development of an evaluation strategy that includes development of test issues, independent variables (test factors) and dependent variables (test measures). Embedded within this process is an exploratory analysis process that can be conducted to prioritize and construct an effective and efficient test design.

CTM 1.2 Develop Evaluation Strategy has five sub-processes (level 3 steps), shown in Figure 2-2. Four of the five sub-processes require analytical input and participation: CTM 1.2.1 Identify & Collect Evaluation Inputs, CTM 1.2.2 Develop CCIs/COIs, CTM 1.2.3 Establish T&E Strategy Framework, and CTM 1.2.4 Develop Risks and Mitigations. The fifth sub-process, CTM 1.2.5 Develop Infrastructure Strategy, is described in the Action Officer's handbook as a part of the Infrastructure sub-thread Since the first four of these sub-processes are critical to the evaluation of the capability, detailed information on the development of an evaluation strategy can be found in Annex B of this handbook.

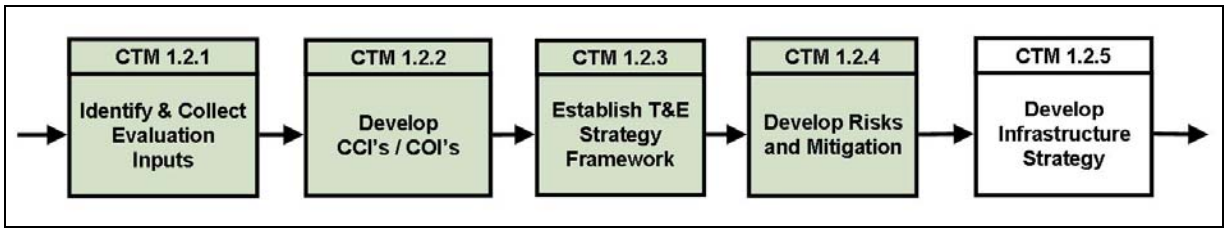

Figure 2-2. CTM 1.2 Develop Evaluation Strategy

CTM 1.2.1 *Identify and Collect Evaluation Inputs.* This sub-process is important to identify the collection of inputs explicitly as a process to ensure that the analysis team makes an explicit effort to identify and gather all of the necessary documentation as the first activity. This includes documents that describe the capability gap, provide relevant capability analysis designs and results, provide relevant T&E results, and identify key stakeholders of the capability, its SoS and sub-systems.

CTM 1.2.2 *Develop CCIs/COIs.* This sub-process defines the critical issues that must be addressed in the test that can be used to assess performance as it pertains to capabilities supporting joint missions. COIs address SUT performance and capability contribution to SoS operational effectiveness; and critical capability issues (CCI) address joint capability contributions to achieving mission-desired effects. These issues (CCI and COI) should be carefully structured to address the key capability attributes described in joint capabilities documentation (Initial Capabilities Document [ICD], CDD, and so forth). It is important to state how the test issue contributes to achieving the desired mission end state in terms of mission-desired effects. CCIs should address the SoS' ability to accomplish joint operational tasks or the SoS, system, or Service attribute performance. On the other hand, COIs focus on SUT abilities to perform tactical tasks. COIs are the operational effectiveness and operational suitability issues (not parameters, objectives, or thresholds) that must be examined in OT&E to evaluate/assess the system's capability to perform its mission tasks. The analyst maintains overall responsibility to ensure the test issues are developed and support the evaluation strategy. Actual drafting of the

issues may come from the operational community of interest as provided for in applicable Service doctrine and organization.

CTM 1.2.3, *Establish Test and Evaluation Strategy Framework.* This sub-process defines the test space that will provide the basis for the evaluation of the capability. It will define the SoS test factors, conditional test factors, and the measures for analyzing JMe, task performance, and SoS performance. Within this sub-process is the opportunity to conduct exploratory analysis that will help to reduce the test space by prioritizing the test factors. Annex C provides further information on the exploratory analysis process

CTM 1.2.4, *Develop Risks and Mitigation.* This sub-process identifies and characterizes risks, particularly those associated with the assumptions and modeling capabilities used during the analysis process, and to develop a risk mitigation plan.

CTM 1.3, *Develop the JOC-T.* This sub-process draws upon the various authoritative sources to define the operational organizations, resources, missions, environment, and threats that interact with the SoS. Developing the JOC-T includes performing operational and systems analyses to define the relevant set of operational and systems elements and interactions for capability tests. This process will identify source documents and organizations for development of the TEMP. During JCIDS, capability gaps are identified in the achievement of mission-desired effects and in the performance of essential tasks. Figure 2-3 shows the CEM representation of JOC-T development.

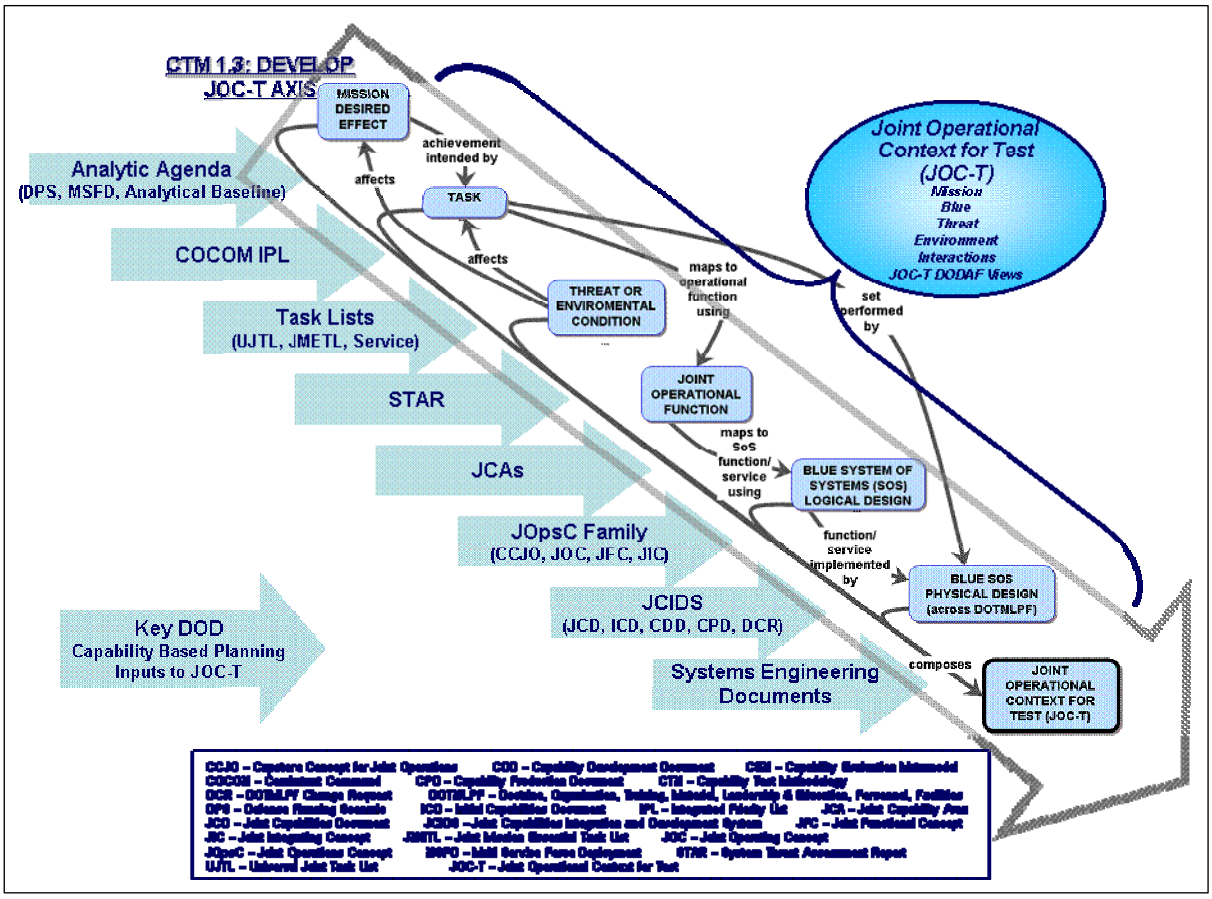

Figure 2-3. CEM Representation of CTM 1.3 Develop JOC-T

The JOC-T should include a capability's relevant mission aspects (for example, mission statement, mission-desired effects, mission end state) and essential tasks (for example, doctrine/concept of operations [CONOPS] with major phasing, Joint Mission Essential Task List [JMETL], UJTL, and Service tasks). Threat and environmental conditions are also identified which affect achievement of mission-desired effects or affect performance of essential tasks. Threat conditions include those threat condition variables of an operational environment or situation, for example, threat actions, threat order of battle, threat command and control (C2) structure, threat systems, threat force lay down, in which a unit, system, or individual is expected to operate and which may affect achievement of mission-desired effects or affect performance of essential tasks. Environmental conditions include those physical environment condition variables of an operational environment or situation, for example, land, sea, air, and space; or civil environment condition variables of an operational environment, for example, political, cultural, and economic, in which a unit, system, or individual is expected to operate and which may affect achievement of mission-desired effects or affect performance of essential tasks.

As the capability development focus transitions to functional analysis and allocation, capability gaps are mapped to operational functions using the JCA functional taxonomy. JCAs have been recently streamlined to focus on operational functions, such as C2 and force application. In order to create a systems engineering logical model, a capability's desired effects and essential task gaps are addressed by a blue SoS logical design, which incorporates non-materiel and

materiel functionality and services across DOTMLPF. Blue logical design elements include: mappings of the UJTL, essential joint tasks, Service tasks to JCA operational functions and system functions, SoS context, task organization, C2 structure, and force lay down with logical groupings of primary nodes. This blue logical design is then implemented in a blue SoS physical design during systems engineering design synthesis activities. The physical design includes descriptions of the components, services, and other interfaces necessary to implement an SoS logical design. As described above, the JOC-T is composed of mission, task, condition, and SoS elements and element interactions (for example, blue to threat, blue to blue, threat to threat, blue to environment, threat to environment) of a capability.

The JOC-T should specify:

- Mission objectives, for example:
  - Mission statement
  - Mission-desired effects
  - Mission end state
- Blue forces, for example:
  - System capability requirements
  - System means to implement those requirements
  - System operating limitations
  - SoS context
  - Task organization
  - C2 structure
  - Force lay down with logical groupings of primary nodes
- Blue actions, for example:
  - UJTL/Service tasks
  - JCA critical elements
  - Task steps
  - Doctrine/CONOPS with major phasing
- Environment conditions, for example:
  - Physical conditions
  - Civil conditions
- Threat forces, for example:
  - Threat order of battle
  - C2 structure
  - Systems
  - Threat lay down
  - Threat actions
- Interactions, for example:
  - Blue to threat
  - Blue to blue
  - Threat to threat
  - Blue to environment
  - Threat to environment

The JOC-T includes several blue force and threat force operational and system views from the DoDAF. These products are discussed later in this handbook, where appropriate, as inputs into

subsequent processes. By completing the operational and systems views, the tester is able to determine the blue and threat actions, the sequence diagrams and phasing of maneuver, the interactions, and the environmental effects. The JOC-T will also include discussions of both the physical and civil environmental aspects as well.

There are six level 3 sub-processes in CTM 1.3. Each of these requires analytical input: 1.3.1 Analyze the Mission, 1.3.2 Analyze Blue Forces, 1.3.3 Analyze Environment, 1.3.4 Analyze Threat Forces, 1.3.5 Compose Joint Operational Context, and 1.3.6 Validate JOC-T. Figure 2-4 depicts the sub-processes of CTM 1.3 Develop the JOC-T.

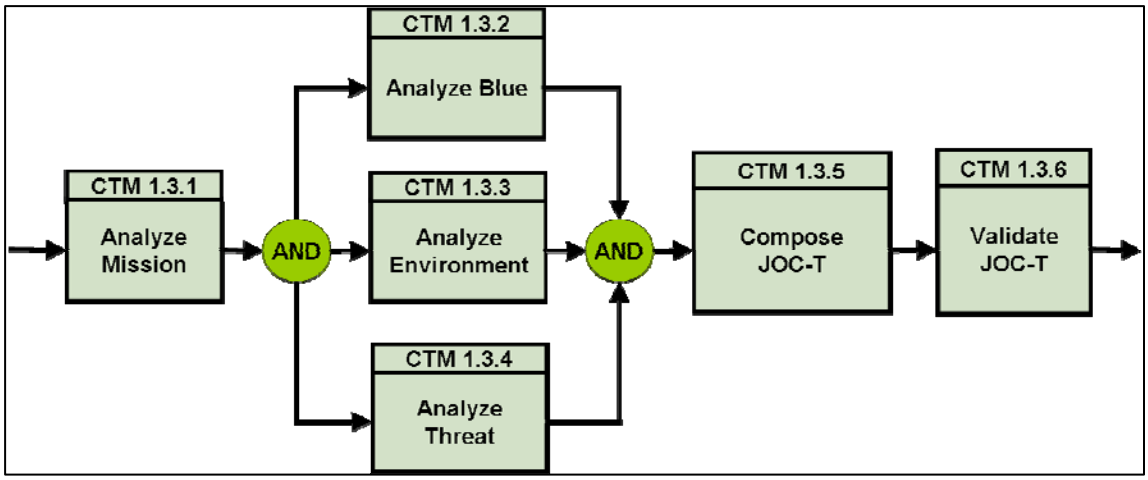

Figure 2-4. CTM 1.3 Develop JOC-T

CTM 1.3.1 *Analyze Mission.* This sub-process establishes a high-level description of the mission that is to be performed by the capability. It should include an operational overview OV-1 that identifies the mission statement, mission objectives, and mission-desired effects. The identification of desired effects will be important to measuring mission effectiveness.

CTM 1.3.2 *Analyze Blue.* This sub-process defines the major components of the blue forces and the tasks which must be performed to accomplish the mission objectives and desired effects. This may include a number of DoDAF products that describe any unique aspects of blue force operations as well as the interactions between blue forces, their architecture, and the environment. A critical part of the blue force description is the determination of the joint tasks. In accordance with JCIDS, a task is an action or activity assigned to an individual or organization to provide a capability. The functional area analysis (FAA) identifies the operational tasks, conditions, and standards needed to achieve military objectives. The FAA produces a prioritized list of tasks that are necessary to achieve the mission objectives. Joint tasks are derived from the UJTL. When augmented with the Service task lists, the result is a comprehensive integrated menu of functional tasks, conditions, measures, and criteria. This list of tasks will serve as the basis for identifying the Task MOPs.

CTM 1.3.3 *Analyze Environment.* This sub-process defines the environment to include the air, water, land, plants, animals, and other living organisms, man-made structures, historical and cultural resources, and the interrelationships that exist among them. Analysis of the environment

involves examining environmental conditions that are potential T&E factors, and should be identified as input into the development of the evaluation strategy. Environmental conditions are broken down as either physical or civil. The physical environment includes both natural and man-made environments, and could extend to geospatial, meteorological, oceanographic, and space. Physical environment can include both external and internal conditions (such as temperature, humidity, radiation, magnetic and electric fields, and shock vibration). SoS environment descriptions should include SoS influences that would affect the performance, reliability, or survivability of the SoS. If key to the testing of the SoS, the physical environment description should include possible modes of transportation into and within expected areas of operation and existing infrastructure support capabilities. The civil environment includes local indigenous customs, economic, ethnic, political and religious factions or groups, group history and inter-relationships, general population views toward blue and threat forces, and so forth. An understanding of the environment will serve as a basis for conditional factors in the test design.

CTM 1.3.4 ***Analyze Threat.*** This sub-process analyzes the potential strengths, capabilities, and strategic objectives of any adversary that can limit or negate US mission accomplishment or reduce force, system, or equipment effectiveness. The authoritative source is a Defense Intelligence Agency (DIA) (or its designate) Initial Threat Warning Assessment (ITWA). The ITWA will identify adversarial capabilities that could specifically affect missions and functions being assessed in a Capability Based Assessment. The operational threat represents threat system/SoS capabilities, threat tactics, and threat doctrine. The environment for these operations may include threat force employment; electronic countermeasures; a simulated nuclear, biological, and chemical (NBC) environment; and other battlefield obscuration. The operational environment addresses all operational requirements and specifications required of the SoS to include the individual system platforms. It establishes the geographical and environmental conditions in which the SoS will operate. Different operating environments and their characteristics will affect support requirements. Threat conditions are the variables of an operational environment in which the SoS is expected to operate that may affect the performance of the SoS. The threat conditions describe the strengths and capabilities of an adversary that directly affect SoS effectiveness. It is these threat conditions that form the basis in the evaluation strategy for additional factors that will impact the test design.

CTM 1.3.5 ***Compose JOC-T.*** This sub-process uses the information developed in the analysis of blue, environment, and threat, and the mission context to prepare the JOC-T. This should include a description of the joint mission, the joint tasks, the SoS, blue force descriptions, the threat descriptions, and the physical environment and civil environment. Those environment and threat conditions that may be considered as test factors in the evaluation strategy should be listed and described as part of the JOC-T.

CTM 1.3.6 ***Validate JOC-T.*** In this sub-process, the verification, validation and accreditation (VV&A) team validates the JOC-T as an authoritative distillation or abstraction of the "real world" represented by authoritative sources. See the AO Handbook for additional detail on the VV&A process. Validation is the process of determining the degree to which the JOC-T is an accurate description of the real world from the perspective of the intended uses of the eventual LVC-DE. The JOC-T needs to have sufficient detail to enable a comparison with the LVC-DE

to satisfy user validation. The JOC-T is validated by comparison to authoritative sources including:

- Analytic Agenda (Defense Planning Scenarios [DPS], Multi-Service Force Deployment [MSFD], Analytical Baseline)
- Combatant Command (COCOM) Integrated Priority List (IPL)
- Task Lists (UJTLs, JMETLs, Service tasks)
- System Threat Assessment Report (STAR)
- JCAs (Tier 1: C2, Battlespace Awareness, Net Centric, Logistics, Building Partnerships, Protection, Force Support, Force Application, Corporate Management and Support)
- Joint Operations Concept (JOpsC) family (Capstone Concept for Joint Operations [CCJO], Joint Operating Concept [JOC], Joint Functional Concept [JFC], Joint Integrating Concept [JIC])
- CONOPS documents
- JCIDS (Initial Capabilities Document [ICD], CDD, CPD, DOTMLPF Change Request [DCR])
- Systems Engineering documents

The fidelity of the eventual LVC-DE will be correlated to the evaluation strategy so as to tailor system representations to meet test and user validation requirements.

CTM 1.4 *Develop/Refine Capabilities Crosswalk.* During this sub-process a preliminary capabilities crosswalk is produced mapping critical T&E issues to mission-desired effects, tasks, conditions, and system/SoS elements. The dependent variables derived from capability crosswalk are the Mission MOE, the Task MOPs, and the MOSAs. These are mapped to the SoS characteristics across DOTMLPF and mission conditions (threat and environment) which are the independent variables. The capability crosswalk shows the flow from JCAs to UJTLs to measures and desired effects. It is the primary tool for ensuring that the measures and data elements are mapped to joint capabilities and key test issues, and for documenting that mapping. This document references the capabilities crosswalk. The capabilities crosswalk is discussed in more detail in appendix E. The analyst should lead the development of the capabilities crosswalk in support of the overall evaluation strategy and test design. CTM 1.4 has no level three sub-processes.

CTM 1.5 *Develop Integrated T&E Programmatic Summary.* It is necessary to complete an initial estimate of the integrated T&E programmatic summary, CTM 1.5, Develop Integrated T&E Programmatic Summary. CTM 1.5 does not have an evaluation focus and it is not discussed further in this handbook. See the Action Officer's Handbook for additional information on CTM 1.5.

2.2 Instructions for CTM 1.1 Develop Capability / System of Systems Description

This section described the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 1.1.

(1) **Purpose:** The analyst must understand the capability that is being tested, the gap which it will fill, and be able to describe the SoS and systems that will be involved in the test.

(2) **Discussion:** This process, CTM 1.1 Develop Capability/System of Systems Description, is a primary input into the development of the evaluation strategy, which initiates the evaluation thread of the CTM. An SoS is a set or arrangement of interdependent systems that are related or connected to provide a given capability. The loss of any part of the system will significantly degrade the performance or capabilities of the whole. Thus to fully describe the capability, the SoS must be decomposed into testable systems that can be integrated into the JME. SoS attribute areas may also be identified from capability gaps and key characteristics. The analyst must have a clear comprehensive understanding of the SoS that will be tested in order to identify test factors and measures that will form the evaluation strategy.

(3) **Tools and Techniques:** The capability should be described in detail in appropriate JCIDS documents (ICD, CDD, CPD) and therefore should be straightforward in gathering the necessary information. Any voids in descriptions or other uncertainties should be addressed with the PMs and key stakeholders.

(4) **Inputs:** Figure 2-5 identifies sources of information that are desired for executing this section of the CTM. Described below are those required inputs; if they exist. The remaining sources are optional.

Recommended Input Info/Sources	Products	Example
1.1 Develop Capability/SoS Description		
▪ Joint Capability Areas (JCA) ▪ Initial Capabilities Document (ICD) ▪ Capability Development Document (CDD) ▪ Capability Production Document (CPD) ▪ Doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) Change Request (DCR) ▪ Other Test Plans (Developmental Test [DT], Operational Test [OT], Live Fire [LF] Test) ▪ Approved Analysis of Alternatives (AoA) Plan ▪ Analytical Baseline (DPS, MSFD, FYAB)	❑ a. Capability/SoS Description	
	❑ b. Capability/SoS OV-1	Figure 2-6

Figure 2-5. CTM 1.1 Develop Capability/SoS Description Checklist

Initial Capabilities Document (ICD). "The ICD documents the requirement for a materiel or non-materiel approach, or an approach that is a combination of materiel and non-materiel, to satisfy specific capability gap(s). It identifies required capabilities and defines the capability gap(s) in terms of the functional area, the relevant range of military operations, desired effects, time and doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) and policy implications and constraints. The ICD summarizes the results of the DOTMLPF and policy analysis and the DOTMLPF approaches (materiel and non-materiel) that may deliver the required capability. The outcome of an ICD could be one or more joint DCRs or recommendations to pursue material solutions.."[19]

Capability Development Document (CDD). "The CDD captures the information necessary to develop a proposed program(s), normally using an evolutionary acquisition strategy. The CDD outlines an affordable increment of militarily useful, logistically supportable, and technically mature capability. The CDD may define multiple increments if there is sufficient definition of the performance attributes (KPPs, KSAs, and other attributes) to allow approval of multiple increments."[20]

Capability Production Document (CPD). "The CPD addresses the production elements specific to a single increment of an acquisition program."[21]

[19] CJCSI 3170.01G, Joint Capabilities Integration and Development System, 1 March 2009.

[20] Ibid.

[21] Ibid.

DOTMLPF Change Request (DCR). "The joint DCR defines the implementation of recommendations to change joint DOTMLPF and policy from USJFCOM or other sponsors of joint experimentation…, joint testing, and evaluation… activities." [22]

Analysis of Alternatives (AoA). The AoA is an analytical comparison of the operational effectiveness, suitability, and lifecycle cost of alternatives that satisfy established capability needs. It is a vehicle used by senior leadership to debate and assess a program's desirability and affordability. Initially, the AoA process typically explores numerous conceptual solutions with the goal of identifying the most promising options, thereby guiding the Materiel Solution Analysis Phase. An AoA is important in determining whether or not a system should be procured. It must make a case for having identified the most cost effective alternative and it must also make a compelling statement about the military utility of acquiring it.

Joint Capabilities Evaluation (JCE). The JCE documents the analysis of one or more relevant capability test events used to support major milestone decision points.

Capability Gap Evaluation Areas. The capability gap evaluation areas are developed in terms of the JCA, JOpsC key characteristics, functional area(s), mission, desired effects, tasks, constraints, limitations, and key attributes across the spectrum of DOTMLPF with appropriate measures.

Attributes of Capabilities. The capability gap discussion should also describe the attributes of the required capabilities in terms of desired outcomes. Where multiple characteristics are identified, they should be prioritized based on their value to delivering the capability within the context of the CONOPS described earlier.

(5) **Actions:** The analyst will work with the test director and test planners to gather the necessary information to describe the capability under test.

Review required inputs. Review the required inputs for descriptions of the capability, the identified gap(s), the SoS and other systems that will support the test.

Capture the Descriptives. Capture and list the overall capability, the SoS description, systems that will be tested, test factors, KSAs, and pertinent mission, task, and system measures. A list of commonly used system and SoS characteristics and attributes is provided as a reference in annex M.

Determine Alternative SoS Configurations. Determine if different configurations of the SoS are feasible or should be considered in the test design. Determine what the materiel and non-materiel factors are that will be part of the test design. Conduct a

[22] Ibid.

mapping of systems to SoS configurations and identified joint capability key characteristics. See Figure 2-7 for an example.

Capture key stakeholders. List key stakeholders for the systems under test.

(6) **Products:** The output from this process is a complete descriptive of the capability. The analyst will develop some products that will support the evaluation strategy. These products are:

Draft OV-1 that defines the capability/SoS. Note that additional mission and task information will be added to the OV-1 in CTM 1.3. See Figure 2-6 for an example.

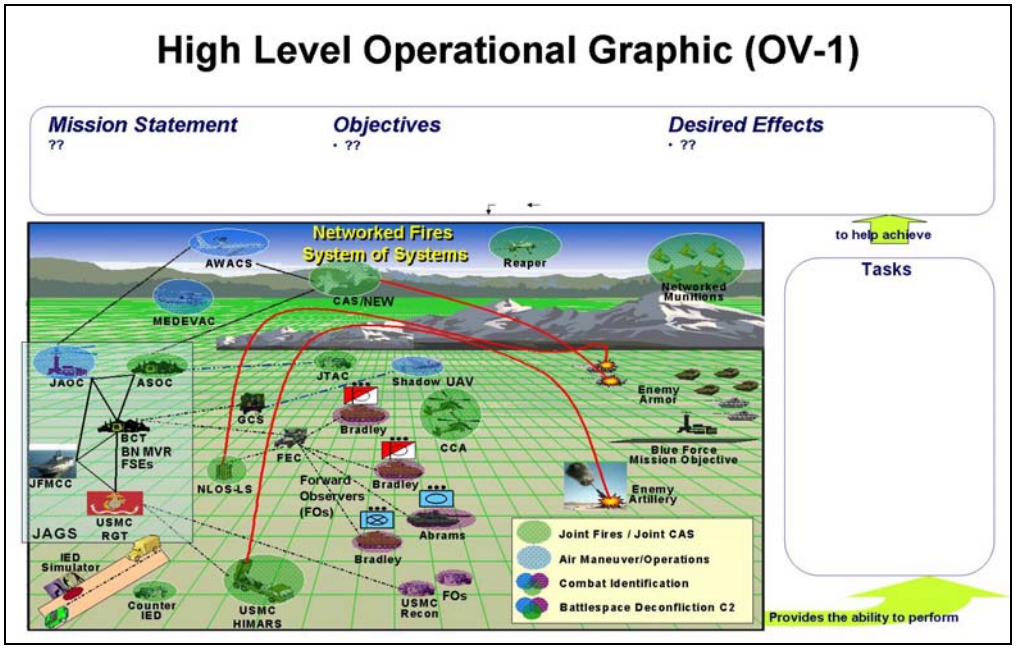

Figure 2-6. OV-1 Example

List and mapping of SoS configurations to systems and to key characteristics. If different SoS configurations are considered, a mapping of systems to those configurations should be conducted. Joint capability key characteristics should also be mapped to those SoS configurations. Figure 2-7 is an example of SoS mapping. For example, the current Joint Air-to-Ground System (JAGS) SoS configuration (the second column) is linked to the forward observer (FO) system (first row under Systems) and all four of the SoS characteristics. Each linkage is denoted by the cells containing an "x". The asterisk denotes both materiel and non-materiel associations such as doctrine, organization, training, materiel, leadership and education, personnel and facilities (DOTMLPF).

JBD2 System of Systems (SoS) Configurations

SoS Configurations	Current JAGS	Future JAGS	
Systems			
FO	X	X	
CJTF	X	X	
JAOC	X	X	
ASOC	X	X	
Air C2	X	X	
Ground C2	X	X	
UAS	X	X	
TBMCS	X		
TAIS	X		
JASMAD		X	
JAMUS		X	
			SoS Characteristics
	X*	X*	Speed of Command
	X*	X*	Interoperability across systems
	X*	X*	Force agility
	X*	X*	Positive Identification

* Materiel & Non-Materiel

ASOC – Air Support Operations Center **C2** – Command and Control **CJTF** – Commander, Joint Task Force
DOTMLPF – Doctrine, Organization, Training, Materiel, Leadership & Education, Personnel, Facilities **FO** – Forward Observer
JAGS – Joint Air-to-Ground System **JAMUS** – Joint Aviation, Missile, and Unmanned Systems **JAOC** – Joint Air Operations Center
JASMAD – Joint Airspace Management & Deconfliction **TAIS** – Tactical Airspace Integration Systems
TBMCS – Theater Battle Management Core System **UAS** – Unmanned Aerial System

Figure 2-7. SoS Mapping to Systems and Key Characteristics

List of systems and their key stakeholders. A list of systems with each key stakeholder will be beneficial to further development of the evaluation strategy. Analysts will need to identify contacts for each of the key stakeholders.

Note that the sequential numbering of the CTM calls for CTM 1.2 Develop Evaluation Strategy to occur next.

However, as mentioned earlier, several of these processes and sub-processes are done in parallel. Since the evaluation thread calls for certain components of the JOC-T to be described before developing the evaluation strategy, the analyst will need to begin developing the JOC-T before developing the evaluation strategy.

2.3 Instructions for CTM 1.3 Develop the Joint Operational Context for Test (JOC-T)

This section describes the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 1.3.

(1) **Purpose:** The analyst must understand the context in which the capability will be tested that includes the mission, the blue (friendly) forces, the threat, and the environment.

(2) **Discussion:** This JOC-T draws upon the various authoritative sources to define the operational organizations, resources, missions, environment, and threats that interact with the SoS. Products of this process include mission, blue SoS, threat, environment, and interaction descriptions. As described above, the JOC-T is composed of mission, task, condition, and SoS elements and element interactions (for example, blue to threat, blue to blue, threat to threat, blue to environment, threat to environment) of a capability. The JOC-T should specify mission objectives, blue forces, blue actions, environment conditions, threat forces, and force interactions.

(3) **Tools and Techniques:** Various pieces of the JOC-T should be described in detail in appropriate JCIDS documents (ICD, CDD, CPD) and therefore should be straightforward in gathering the necessary information. Any voids in descriptions or other uncertainties should be addressed with the PM(s) and key stakeholders.

(4) **Inputs:** Figure 2-8 identifies sources of information that are desired for executing this section of the CTM. Described below are additional inputs not previously described in this chapter; the remaining sources not described are considered optional.

Joint Operations Concept (JOpsC). The JOpsC family of concepts consists of the CCJO, JOCs, JFCs and JICs. JOpsC family concepts are written using a "problem - solution" method. They identify military problems and propose solutions for innovative ways to conduct operations, going beyond merely improving the ability to execute missions under existing standards of performance. They are a visualization of future operations and describe how a commander, using military art and science, might employ capabilities necessary to meet future military challenges. Ideally, they will produce military capabilities that render previous ways of warfighting obsolete and may significantly change the measures of success in military operations overall. They may be found at the Joint Staff J7 Joint Experimentation, Transformation, and Concepts Division (JETCD) website.[23]

Universal Joint Task List (UJTL). The primary authoritative source for joint tasks is the UJTL.[24] This document should be the primary source for determining the key joint tasks required to achieving the mission-desired effects, and the standards associated with the tasks. In some cases, particularly for a unique capability, there may be one or more required tasks that cannot be found in the UJTL. In those cases, the analysis should identify those tasks and document their source.

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[23] http://www.dtic.mil/futurejointwarfare/index.html

[24] CJCSM 3500.04E U*niversal Joint Task List (UJTL) Manual*, version of August 1, 2005, updated until 25 Aug 08.

Recommended Input Info/Sources	Products	Example
1.3 Develop JOC-T		
❑ Capability/SoS Description ❑ Joint Capability Areas ❑ Universal Joint Task List (UJTL) ❑ Joint Operations Concept (JOpsC) Family (Joint Operating Concept [JOC], Joint Integrating Concept [JIC], Joint Functional Concept [JFC]) ❑ Initial Capabilities Document (ICD) ❑ Capability Development Document (CDD) ❑ Capability Production Document (CPD)	❑ a. Joint Operational Context for Test (JOC-T)	
⇩		
1.3.1 Analyze Mission		Fig. 2-10
1.3.2 Analyze Blue		Fig. 2-11, Fig. 2-12
1.3.3 Analyze Environment		Fig. 2-13
1.3.4 Analyze Threat		Fig. 2-13
1.3.5 Compose JOC-T		
1.3.6 Validate JOC-T		

Figure 2-8. CTM 1.3 Develop JOC-T Checklist

(5) **Actions:** The analyst will support the test manager and test planners in the development of the JOC-T.

Analyze Mission. The analyst will understand the mission as defined in the JCIDS documents for the capability. The analyst will list the mission statement, mission objectives, and mission-desired effects. Any identified Mission MOEs will be recorded. A mapping of mission objectives to mission-desired effects, to Mission MOEs will be conducted to allow traceability of measures back to mission effectiveness. See Figure 2-10 for an example.

Analyze Blue. Define the major components of the blue forces and the tasks which must be performed to accomplish the mission objectives and desired effects. Tasks should already be listed in the JCIDS documents for the capability. Additional information on tasks can be found in supporting documentation. Joint tasks are derived from the UJTL for joint tasks and Service task lists for Service related tasks. Support the development of DoDAF products that describe any unique aspects of blue force operations as well as the interactions between blue forces, their architecture, and the environment. Previously identified Task MOPs will be recorded. Conduct a

mapping of Task MOPs to the tasks to the SoS or systems that will conduct the task. See Figures 2-11 and 2-12 for examples.

Analyze Environment. Define the environment in which the capability will operate. Examine and list the environmental conditions that are potential T&E factors. Environmental conditions are either physical or civil. The physical environment includes both natural and man made environments, and could extend to geospatial, meteorological, oceanographic, and space. The civil environment includes local indigenous customs, economic, ethnic, political and religious factions or groups, group history and inter-relationships, general population views toward blue and threat forces, and so forth. An understanding of the environment will serve as a basis for conditional factors in the test design.

Analyze Threat. Determine the threat environment in which the joint capability will operate in. The environment for these operations may include threat force employment, electronic countermeasures, a simulated NBC environment, and other battlefield obscuration. Threat conditions are the variables of an operational environment in which the SoS is expected to operate that may affect SoS performance. List those threat conditions that may be considered as factors that directly affect SoS effectiveness. These threat conditions may need to be included in the evaluation strategy as additional factors that will impact the test design.

(6) **Products:** The output of this process is a JOC-T document that describes the context for the test. The test planners with analyst support should construct this document. Included will be several blue force and threat force operational and system views from the DoDAF that can aid in defining the context for the test. The analyst will develop some additional products that will be included in the JOC-T. These products are:

Completed OV-1 with mission and task information included. See Figure 2-9 for an example.

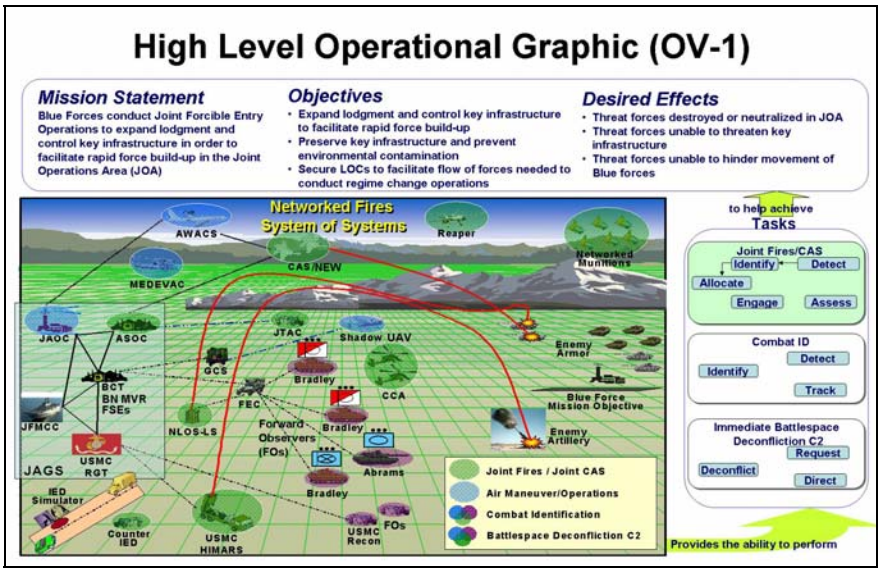

Figure 2-9. Completed OV-1

List and mapping of the mission statement, mission objectives, mission-desired effects, and mission measures of effectiveness (Mission MOE). This is a mapping of mission level measures to the mission statement that will provide the traceability for mission effectiveness. This is the "Analyze Mission" in the handbook checklist. See Figure 2-10 for an example.

Mission: Joint Forcible Entry

Mission Statement: On order, Blue forces conduct joint forcible entry operations to expand lodgment and control key infrastructure in order to facilitate rapid force buildup in the Joint Operating Area (JOA).

Objectives	End State	Desired Effects	Threat forces destroyed or neutralized in JOA	Threat forces unable to threaten key infrastructure	Threat forces unable to hinder movement of Blue forces	
Expand lodgment and control key infrastructure to facilitate rapid force build-up	Expand lodgment and control key infrastructure		P	S		
Preserve key infrastructure and prevent environmental contamination	Key infrastructure preserved without environmental contamination		P	P		
Secure LOCs to facilitate flow of forces needed to conduct regime change operations	LOCs secured		P		P	
						Mission Measures of Effectiveness
			P	S	S	Threat Systems Combat Ineffectiveness
			P	S	S	Time to Threat Systems rendered ineffective
Legend			P	S	S	Cumulative effectiveness time Threat Systems in JOA
P: Primary relationships to Desired Effects			S	P	P	Blue control of JOA
S:Secondary relationships to Desired Effects			S	P	S	Key infrastructure vulnerability
			S	S	P	Blue force vulnerability

Figure 2-10. Mission Decomposition & Mapping

List and mapping of joint and Service tasks that will be performed by the capability under test. This mapping will show the relationship of the SoS configurations to the tasks that they will perform that will achieve mission-desired effects. See Figure 2-11 for an example.

					SoS Configurations
	X	X	X	X	Current JAGS
	X	X	X	X	Future JAGS
Tasks	TA 5.x Execute Immediate Battlespace Deconfliction C2	TA 3.2.2 Conduct Close Air Support	TA 3.2.1 Conduct Joint Fires	TA 6.5 Provide for Combat ID	Desired Effects
	X	X	X		Destroyed or neutralized Threat Forces (in-Zone, moving into Zone, indirect fires, ADA)
	X	X	X		Blue unhindered in maneuver within the JOA
	X	X	X	X	Blue force survivability in the JOA

Figure 2-11. Task to Mission Mapping

List and mapping of joint and Service tasks to task measures of performance (Task MOP). This mapping will show the relationship of Task MOPs to the tasks. See Figure 2-12 for an example. The examples in Figures 2-11 and 2-12 fall under "Analyze Blue" in the handbook checklist.

		Joint Tasks				Service Tasks			
	Measures	TA 5.x Execute Immediate Battlespace Deconfliction C2	TA 3.2.2 Conduct Close Air Support	TA 3.2.1 Conduct Joint Fires	TA 6.5 Provide for Combat ID	Service task 1	Service task 2	Service task 3	Service task 4
Task Measures of Performance (TMOP)	Time to C2 Indirect Fires	X	X	X	X				
	Time to C2 Indirect Fires by task thread	X	X	X					
	Time to C2 Indirect Fires when airspace is controlled by requesting Service	X	X	X					
	Time to C2 Indirect Fireswhen airspace is controlled by another Service	X	X	X					
	Number of Indirect Fires denied		X	X					
	Time to get ordnance on target after initiating air-to-surface attack request		X						
	Percent of requested missions executed		X	X					
	Number targets attacked IAW requests for fires		X	X					
	Time to get ordnance on target after initiating task	X	X	X					
Measures of Effectiveness (MOE)	Measure of Effectiveness 1					X			X
	Measure of Effectiveness 2					X	X		
	Measure of Effectiveness 3						X	X	
	Measure of Effectiveness 4						X		X

Figure 2-12. Task MOP to Task Mapping

List of threat and environmental condition factors that may be considered in the evaluation strategy. Include a determination of levels for each factor. This may be in table form with the possible combinations of factors that can be considered in the test. See Figure 2-13 for an example of factors with two levels each. This figure displays both an "Analyze Threat" and an "Analyze Environmental" example as referenced in the handbook checklist.

Threat Factors	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Environment Factors	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Condition Sets												
C 1	1	1	-1	1	-1		1	1	1	1	1	1
C 2	-1	1	1	1	-1		-1	-1	1	-1	-1	1
C 3	-1	-1	-1	-1	1		-1	-1	-1	-1	-1	1
C 4	1	-1	1	-1	1		1	-1	-1	-1	1	1
C 5	1	1	-1	-1	1		-1	1	1	-1	1	1
C 6	-1	-1	1	1	-1		-1	1	1	-1	1	1
C 7	1	1	-1	1	-1		-1	-1	-1	-1	1	1
C 8	-1	1	1	1	-1		-1	-1	1	-1	1	-1
C 9	1	1	1	-1	1		1	-1	1	1	1	-1
C 10	1	-1	-1	1	1		1	1	-1	-1	1	-1

Figure 2-13. Threat and Environmental Conditions

2.4 Instructions for CTM 1.2 Develop Evaluation Strategy

This section described the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 1.2. Since this is a critical component to the evaluation thread, this section of the CTM is explained in more detail in Annex B.

(1) **Purpose:** The analyst must develop the evaluation strategy that will drive the entire capability T&E process. This includes the development of joint and Service issues, Mission MOEs, Task MOPs, system/SoS attribute measures, and test factors.

(2) **Discussion:** This process creates the capability evaluation strategy elements that are included in the TEMP. The evaluation strategy is developed based upon identified warfighter needs and includes the capability gaps, solutions, and implementations from the appropriate source documents (including DPS, Analytical Agenda, Initial Capabilities Document [ICD], and Capability Development Document [CDD]). The initial evaluation strategy document will be in the form of a Test and Evaluation Strategy (TES). As stated in the Defense Acquisition Guidebook, "TES is an early T&E planning document that describes the T&E activities starting with Technology Development and continuing through Engineering and Manufacturing Development into Production and Deployment. Over time, the scope of this document will expand; the TES will evolve into the TEMP due at Milestone B.

The first sub-process in this process, CTM 1.2.1 Identify and Collection Evaluation Inputs, involves the identification and collection of appropriate evaluation inputs. Once all inputs have been collected, the CCIs and COIs will be derived from the warfighter needs that are documented in CTM 1.3 Develop JOC-T. CCIs are used to assess SoS performance pertaining to capabilities that support joint missions. COIs are used to assess System performance that support SoS and task performance. The analyst will then map these CCIs and COIs to an evaluation framework in CTM 1.2.3 Establish Test and Evaluation Strategy Framework that consists of initial test factors, measures, and relationships in order to demonstrate that warfighter needs are adequately addressed. Once the TES framework has been developed, the analyst will complete an initial assessment of risks and possible mitigations in CTM 1.2.4 Develop Risks and Mitigations.

(3) **Tools and Techniques:** Much of this sub-process requires pulling together information from different authoritative source documents to develop the evaluation strategy. However, part of this sub-process allows for a refinement of the test design in prioritizing test factors through an exploratory analysis process. The level of exploratory analysis that is conducted may be limited or extensive depending on time and resources available, but any exploratory analysis that refines the test space into a smaller set of test factors will save time and money over the course of the T&E. This entire exploratory analysis process is explained in greater detail in Annex C.

(4) **Inputs:** Figure 2-14 identifies sources of information for executing this section of the CTM. Described below are additional inputs not previously described in this chapter. Those remaining sources not described are considered optional.

Data Analysis Plan (DAP template). The DAP is a document developed by the analyst to capture the evaluation strategy and to explain how the analysis will be conducted. At this stage in the process, the DAP will probably be a template or shell of a plan that requires specific information pertaining to this T&E. See Annex J.

Recommended Input Info/Sources		Products	Example
1.2 Develop Evaluation Strategy			
	☐	Evaluation Strategy	
1.2.1 Identify and Collect Evaluation Inputs			
▪ Initial Capabilities Document/Capability Development Document ▪ Analysis of Alternatives ▪ Joint Capabilities Evaluation ▪ Joint Operational Context for Test (JOC-T) ▪ Data Analysis Plan (DAP) template	☐	a. Functional Area Analysis Inputs	
	☐	b. Functional Needs Analysis Inputs	
	☐	c. Functional Solutions Analysis Inputs	
	☐	d. Capability Description Inputs	
	☐	e. Relevant Capability Analysis Designs and Results	

Recommended Input Info/Sources	Products		Example
	❑	f. Relevant Test & Evaluation Results	
1.2.2 Develop CCIs and COIs			
▪ Functional Area Analysis Inputs ▪ Functional Needs Analysis Inputs ▪ Functional Solutions Analysis Inputs ▪ Relevant Capability Analysis Designs and Results ▪ Relevant T&E Results ▪ Joint Operational Context for Test (JOC-T) ▪ Joint Capability Area (JCA) – Universal Joint Task List (UJTL)/Service task mapping	❑	a. Critical Capability Issues (CCI)	Fig. 2-15
	❑	b. Critical Operational Issue (COI)	
1.2.3 Establish T&E Strategy Framework			
▪ Joint Operational Context for Test (JOC-T) ▪ Critical Capability Issues ▪ Critical Operational Issues ▪ Capability Crosswalk	❑	Evaluation Strategy Elements to include the following:	
	❑	a. Independent factors: Threat conditions	
	❑	b. Independent factors: Environmental conditions	
	❑	c. Independent factors: System/SoS configurations across DOTMLPF	Fig. 2-16
	❑	d. Dependent measures: Mission measures of effectiveness (MMOEs)	
	❑	e. Dependent measures: Task measures of performance (TMOPs)	
	❑	f. Dependent measures: System/SoS attributes	
1.2.4 Develop Risks and Mitigations			
▪ Evaluation Strategy	❑	a. Identified Risks and Mitigations	Fig. 2-17
1.2.5 Develop Infrastructure Strategy			
▪ JOC-T	❑	a. Infrastructure Strategy	
▪ Evaluation Strategy			

Figure 2-14. CTM 1.2 Develop Evaluation Strategy Checklist

(5) **Actions:** The analyst will lead the process to develop the evaluation strategy as detailed in Annex B.

Identify and Collect Inputs. Identify all possible inputs to the evaluation strategy as well as known stakeholders. See Annex B for more information.

- ***Identify and Collect Capability Gap Evaluation Area Documents.***

- ***Identify and Collect Relevant Capability Analysis Designs and Results.***

- ***Identify and Collect Relevant Test & Evaluation Results.***

- ***Identify Key Stakeholders.***

Develop list of Test Issues. Develop list of test issues that address joint capability contributions to achieving mission-desired effects and SUT performance and capability contribution to SoS operational effectiveness. The analyst maintains overall responsibility to ensure the test issues are developed and support the evaluation strategy. Actual drafting of the issues may come from the operational community of interest as provided for in applicable Service doctrine and organization.

- ***Develop list of Critical Capability Issues***. CCIs address the SoS' ability to accomplish JMe. At the capability level, the measures framework addresses the fundamental joint capability question or issue, "can the joint SoS perform the tasks under a set of standards and conditions which contribute to mission desired effects." Known as CCIs, the focus of the Mission MOE is on measuring task performance and mission effectiveness. The analyst will ensure these test issues are based on the mission, task, and SoS configurations found in the development of the JOC-T. CCIs should be worded in a consistent format of "Assess the ability to perform Task X by SoS configuration Y under a set of Conditions A to achieve Mission Desired Effect Z". See Figure 2-15 for an example.

- ***Develop list of Critical Operational Issues***. COIs focus on SUT abilities to perform tasks. At the component System/SoS level, the Task MOP addresses the ability to perform Service tasks as defined in the COIs. COIs include operational effectiveness and operational suitability issues examined in OT&E to evaluate/assess a system's capability to perform its tasks. Note that performance characteristics exist at both the System and SoS levels.

Identify Test Factors and Levels. The analyst will identify test independent factors within the three dimensions of joint mission, SoS configurations, and joint mission conditions.

- ***Identify Mission Test Factors and Levels.*** The analyst will determine the different missions in which the capability must perform. This should be identified as part of the gap analysis. The analyst will list the various factors and levels of evaluation for each factor.

- ***Identify SoS Configuration Test Factors and Levels.*** The analyst will determine the different possible SoS configurations that may be used in the test. Configurations include both materiel and non-materiel factors of the SoS that may be altered to impact JMe. These test factors are important to the decision maker in identifying SoS solutions. The analyst will list the various factors and levels of evaluation for each factor.

- ***Identify Joint Mission Conditional Test Factors and Levels.*** The analyst will determine the threat and environmental factors that may be used in the test. Threat conditions may vary as materiel or non-materiel aspects of the threat configuration. Environmental factors can be either physical or civil factors. The analyst will list the various factors and levels of evaluation for each factor.

Identify & Refine Test Measures. The analyst will identify measures at the mission, task, and SoS/SUT levels that will support the evaluation of the capability.

- ***Identify Mission Measures of Effectiveness (Mission MOE).*** The analyst will identify all Mission MOEs used to evaluate the capabilities contributions to JMe. This will include identifying data elements and defining key terms used in the data collection and evaluation. The analyst will ensure each Mission MOE is mapped to at least one mission-desired effect. Each mission-desired effect is required to have at least one measure associated with it. The analyst will update the mission decomposition and mapping as needed (see Figure 2-10). The analyst should begin constructing evaluation views (EV) for each Mission MOE as shown in Annex H (DoDAF), and Annex J (sample DAP).

- ***Identify Task Measures of Performance (Task MOP).*** The analyst will identify all Task MOPs used to evaluate the SoS ability to perform joint and Service tasks. This will include identifying data elements and defining key terms used in the data collection and evaluation. The analyst will ensure each Task MOP is mapped to a joint or Service task. Each task under evaluation will have at least one measure associated with it. The analyst will update the task to mission mapping as needed (See Figures 2-11 and 2-12). The analyst should begin constructing evaluation views (EV) for each Task MOP as shown in Annex H (DoDAF) and Annex J (sample DAP).

- ***Identify Measures of SoS/SUT Attributes (MOSA).*** The analyst will identify all MOSA used to evaluate SoS/SUT performance. This will include identifying data elements and defining key terms that will be used in the data collection and evaluation. The analyst should begin constructing EVs for each MOSA as shown in Annex H (DoDAF) and Annex J (sample DAP).

- ***Determine feasible regions for each measure.*** The analyst will identify standards and threshold values for each measure. If not previously documented, these values should come from the key stakeholders. The analyst will state those values in terms of feasible regions of acceptance.

- ***Structure the Measures***. The analyst will determine any relationships between measures. The analyst will also determine what, if any, measures are a higher priority. If possible, the analyst will use SME input to weight each measure by level of importance with the higher weights given to those measures most important.

Explore Factor Selection. The analyst will identify potential resources for conducting exploratory analysis of the test factors to determine further priorities that will help to refine the test space to one that is smaller and more efficient. The analyst may lead or support the exploratory analysis as directed. Results obtained during this process will be analyzed and incorporated into the evaluation strategy products and follow-on test design. Annex C (Exploratory Analysis) provides details for the methods and processes of conducting an exploratory analysis.

Identify Risks and Mitigation. The analyst will identify risks associated with the evaluation strategy that exists because of assumptions, limitations, or constraints. The analyst will characterize the risk based on the level of impact and the expected frequency (or probability) of occurrence. The analyst will determine possible mitigation strategies that will help reduce the frequency or level of outcome. The analyst will document the risks and mitigation strategies in the draft DAP. Annex J contains an example DAP.

(6) **Products:** The output of this process is an evaluation strategy that will be used to design the T&E of the capability. All the products developed in this sub-process are discussed below but should be included in the development of a DAP. It is the responsibility of the analyst to draft and complete this DAP. Specific products are:

List of stakeholders and analyst points of contact.

List of test issues sub-divided by CCIs and COIs. This will be a written list of CCIs and COIs. The list of test issues may be in the form of the crosswalk matrix. See Annex E for more information on developing test issues. See Figure 2-15 for an example on how to draft a CCI.

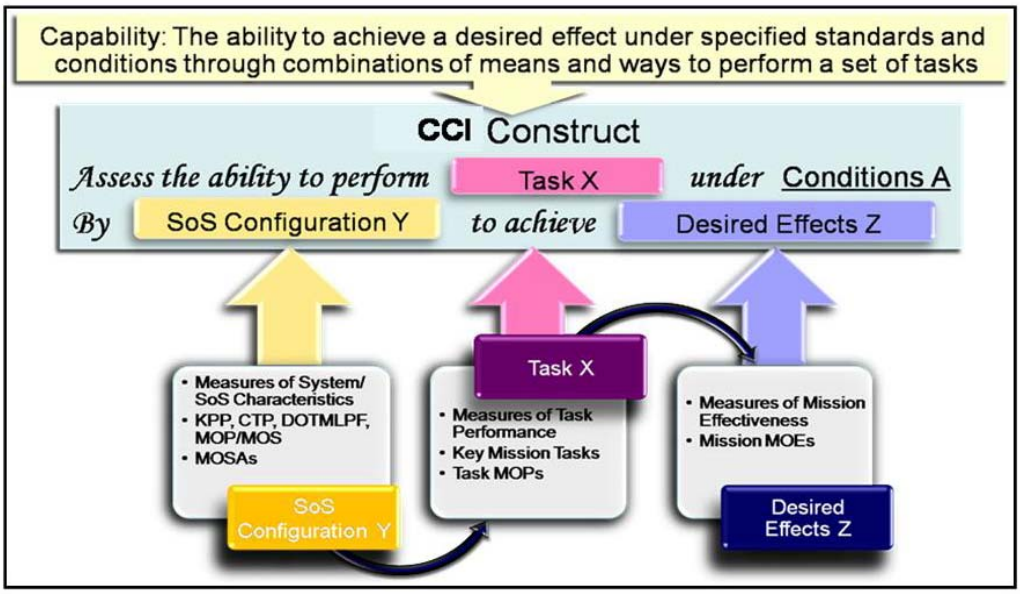

Figure 2-15. CCI Construct Example

List of test factors sub-divided by SoS factors and conditional factors. This will be a follow-on to the conditional factors developed in Figure 2-13. The list will refine the conditional factors as well as identify SoS decisional factors. Included in the list will be identified levels (values) for each factor. See Figure 2-16 for an example for listing additional SoS factors.

SoS Factors	Factor 1	Factor 2	Factor 3
SoS Configurations			
C 1	1	1	1
C 2	1	1	-1
C 3	1	-1	1
C 4	1	-1	-1
C 5	-1	1	1
C 6	-1	1	-1
C 7	-1	-1	1
C 8	-1	-1	-1

Figure 2-16. Example SoS Factors List

List of test measures sub-divided by Mission MOE, Task MOP, and MOSA. Include identified standards, threshold values, priorities, weightings, and

relationships. The list may follow the format of an Integrated Data Requirements List (IDRL). Refer to Annex F for more information on IDRLs.

Updated mission, task, and SoS relational mapping. (See Figures 2-10, 2-11, and 2-12)

Documented exploratory analysis and results. Include any findings, conclusions, recommendations, and decisions that resulted from the analysis. Refine the evaluation strategy based on those decisions. Refer to Annex C for more information on exploratory analysis methods and processes.

Documented risk and mitigation plan for the evaluation strategy. This plan may consist of a table list of risks and possible mitigation processes focused on the ability to conduct an evaluation of the capability under test. Risk assessments may be developed as a part of the plan. Figure 2-17 provides an example 5 x 5 risk matrix based on likelihood of occurrence and consequence of occurrence.

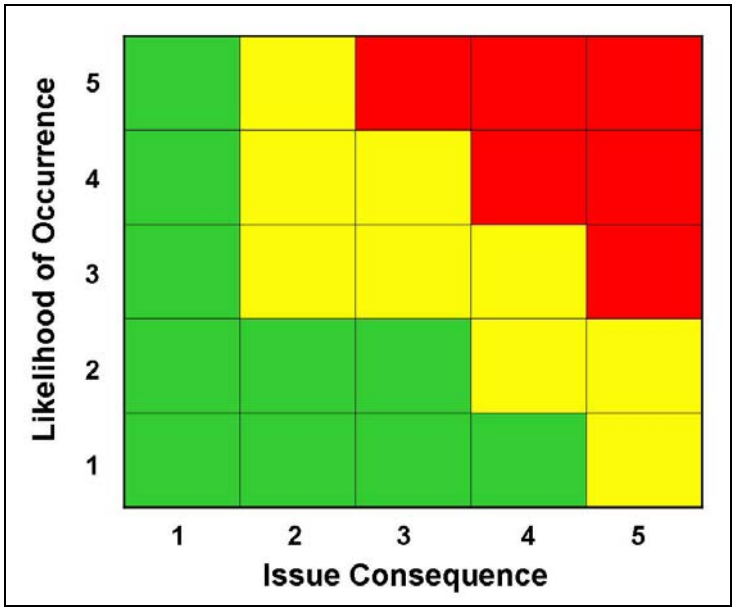

Figure 2-17. Example Risk Matrix

2.5 Instructions for CTM 1.4 Develop/Refine Capabilities Crosswalk

This section described the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 1.4.

(1) **Purpose:** The analyst must develop and refine a capabilities crosswalk to map critical T&E issues to mission-desired effects, tasks, conditions, and system/SoS elements.

(2) **Discussion:** The capabilities crosswalk matrix depicts the key elements of the evaluation strategy. The capabilities crosswalk matrix is a mapping of CCIs to mission-desired effects, tasks, and system/SoS configurations to set the stage for developing capability

evaluation strategies. When the evaluation strategy requires the variation of threat and environmental conditions, these can be additional dimensions of the crosswalk. The capabilities crosswalk documents the key results from the capability/SoS description, JOC-T, CCI development, factor identification, and measure framework. The analyst will use the capabilities crosswalk to document the key results of this process. Completing this capabilities crosswalk matrix allows the planners and analyst to ensure all requirements will be covered in the overall test and evaluation strategy. The capabilities crosswalk is discussed in more detail in Annex E (Capability Crosswalk).

(3) **Tools and Techniques:** Refer to Annex E (Capability Crosswalk).

(4) **Inputs:** Figure 2-18 identifies sources of information that are desired for executing this section of the CTM. Described below are additional inputs not previously described in this chapter. Those remaining sources not described are considered optional.

Evaluation Strategy. A strategy for conducting a test of the SoS across Developmental Testing (DT) and Operational Testing (OT) that support the overall capability T&E.

Recommended Input Info/Sources	Products	Example
1.4 Develop/Refine Capability Crosswalk		
▪ Evaluation Strategy (across life cycle including Development Test [DT] and Operational Test [OT])	❑ a. Capability Crosswalk Matrix	Annex E Fig. E-2

Figure 2-18. CTM 1.4 Develop/Refine Capability Crosswalk Checklist

(5) **Actions:** The analyst will lead the process to develop a capability crosswalk.

Review the Evaluation Strategy. Review the evaluation strategy for issues, measures, and test factors. Determine what areas of the test space will be explored in LVC-DE.

Develop a capability crosswalk. Construct a capability crosswalk that will support the overall evaluation strategy and the development of the DAP.

(6) Products: A matrix of test issues with SoS configurations and measures will be mapped to the issues. This matrix will aid the analyst in determining what issues and measures will be evaluated in future test events. Refer to Annex E for example crosswalk matrices.

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3
CHARACTERIZE AND PLAN TEST

The previous chapter focused on developing an evaluation strategy at the capability level. This chapter focuses on planning a single event to use in the capability evaluation. The relevant issues, test factors, and measures that apply to the test event are drawn from the capability evaluation strategy. This chapter addresses the evaluation thread for CTM 2 Characterize Test, and CTM 3 Plan Test. Section 3.1 provides a description of the steps and processes that are a part of the evaluation thread. Section 3.2 provides a short description of the relevant CEM axes. Follow-on sections in the chapter provide the detailed instructions to guide the analyst in conducting the evaluation methods and processes.

3.1 Capability Test Methodology (CTM) and Processes for CTM 2 and CTM 3

CTM 2 *Characterize the Test.* The second step of the CTM focuses on a sub-set of the capability evaluation strategy. During this step, the analysis team will use the results and insights from ***CTM 1 Develop Test and Evaluation Strategy***, to assist the overall T&E team in characterizing a test event. Characterizing a test includes developing a test concept and an evaluation strategy focused on the single event. This is the first step in taking a conceptual joint capability evaluation strategy and developing a physical event that will result in test data. Figure 3-1 shows the processes (and sub-processes) that are part of CTM 2. The blue highlighted boxes indicate two processes ***CTM 2.1 Develop Test Concept*** and ***CTM 2.2 Refine Evaluation Strategy***, which are parts of the evaluation thread. The analyst should support the development of the test concept and lead the refinement of the test event evaluation strategy. The analyst should be aware of the activities within the technical assessment and programmatic assessment to ensure the evaluation requirements are met.

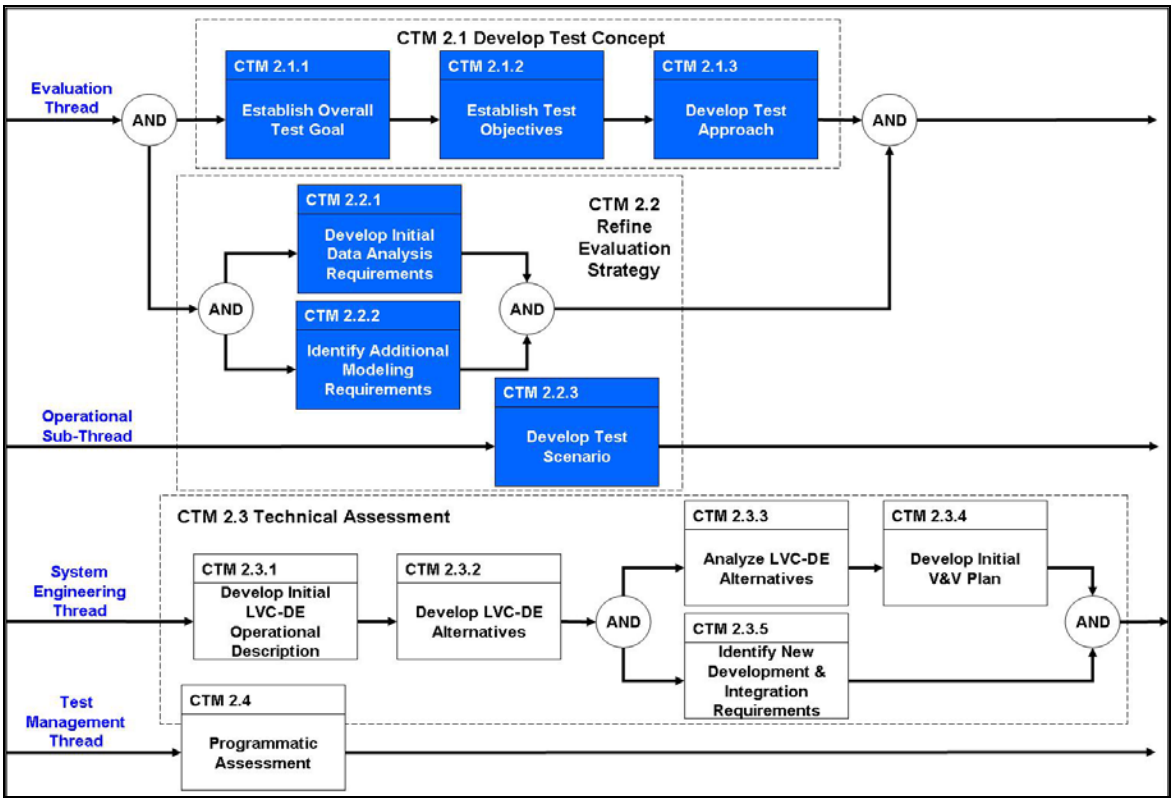

Figure 3-1. CTM 2 Characterize Test

CTM 2.1 *Develop Test Concept.* This process, shown in Figure 3-2, involves activities to establish an overall test goal, establish test objectives, and develop the test approach. In this process, the analyst will be a contributing member of the larger T&E team. The analyst will not have primary responsibility for the CTM 2.1 activities.

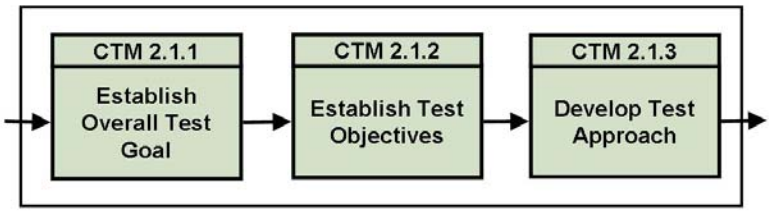

Figure 3-2. CTM 2.1 Develop Test Concept

CTM 2.1.1 *Establish Overall Test Goal.* This sub-process produces test goals. A test goal provides a high-level understanding of the joint capability under test and its contribution to achieving the joint mission. It should establish the purpose of the test and include what specifically the test should accomplish. The test goal clarifies and refines the capabilities of the system/SoS from the perspective of joint testing. To help structure the test goal, the joint mission definition should address the relevant portion of the family of joint future concepts, CONOPS, or UCP-assigned mission to which the joint capability contributes, and the desired end state; this includes those tasks and any enabling capabilities required to achieve the desired mission outcomes (desired end state). Test

goals should be directly traced to joint capability development documents (for example, ICD, CDD). The goals should scope the overall test in terms of the key performance characteristics. A particular test event or iteration will probably not assess all of the key performance characteristics. The test goals will be mapped to the broader TES to show how a test fulfills a portion of the strategy.

CTM 2.1.2 *Establish Test Objectives.* The test objectives identify which customer questions will be tested in the joint environment. Test objectives should be measurable and should describe the purpose of the test. Test objectives focus on the SoS capability contribution to achieving the mission-desired end state and key attributes to be evaluated. These objectives take the form of a series of statements in the following format: "To evaluate the SoS' ability to achieve or contribute to achieving the desired effect." The team should use the JOC-T and the evaluation strategy as starting points for developing SoS test objectives. It is also important to reference the test goals when structuring the detailed objectives. The test objectives, like their parent goals, will be tied directly to attributes of the system/SoS. Test objectives should also:

- Be prioritized based on the SoS capability contribution to achieving the mission-desired end state and key characteristics to be evaluated;
- Be based on SOS and SUT capabilities and contribution to joint capability performance; and
- Tied to MOEs used to assess key performance characteristics of the SoS and mission-desired effects.

This prioritization of test objectives can be accomplished by a risk-management process to identify, assess, and mitigate test-related risks that have an impact on cost, schedule, or performance. Different system PMs and stakeholders included in this prioritization decision will ensure collaboration with the SoS customers.

CTM 2.1.3 *Develop Test Approach.* When a specific test requires unique support, the test approach and necessary support should be described. The test approach provides an initial description of how the test will be accomplished, how the test environment will be structured, and what types of conditions will apply. The test approach should include a macro scope schedule that will identify a general timeline for when test events will take place. For additional detail, see CTM 3.2 Perform LVC-DE Analysis. It is important to reference the high-level test schedule to ensure deconfliction of individual test events with the larger test schedule. The test approach will also identify the planned test facilities for the test. The team should use the test objectives to begin to articulate "how" the system/SoS will be tested. As test event planning proceeds and information becomes more mature, detail will be added regarding what operational entities are required and how they interact. Specific LVC requirements or constraints should be incorporated as part of the test approach. Any operational constraints, such as organization behaviors and rules of engagement (ROE), should be specified. The test-approach description should include operational organizations, resources, missions, and threats that will interact with the test system/SoS.

CTM 2.2 *Refine Evaluation Strategy.* Figure 3-3 shows the sub-processes of CTM 2.2. It refines elements of the previously developed evaluation strategy (in CTM 1). This refinement should be scoped according to the newly-defined test goals and objectives developed in ***CTM 2.1 Develop Test Concept***. Using the evaluation strategy formed in the TES, the analyst will select relevant sections of the initial evaluation strategy for use in the test that is being characterized. The test goal, objectives, and approach are the basis to refine the general test issues, CCIs and COIs, and the evaluation strategy framework.

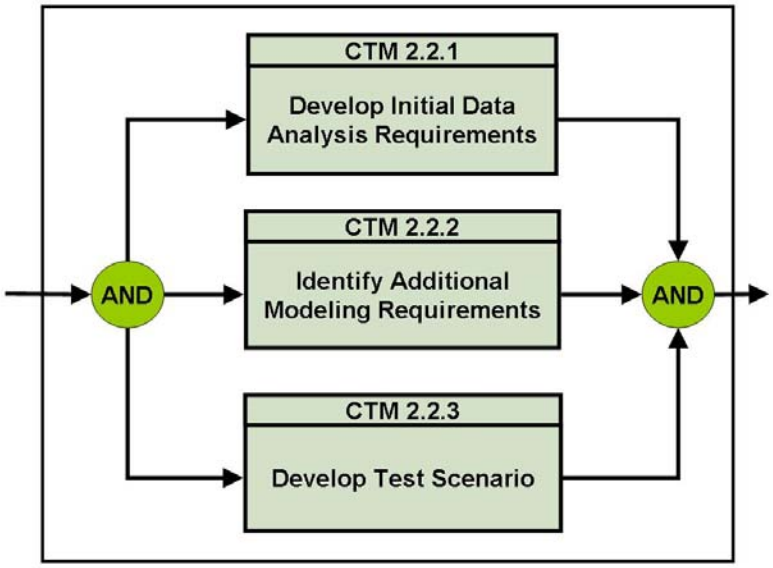

Figure 3-3. CTM 2.2 Refine Evaluation Strategy

CTM 2.2.1 *Develop Initial Data Analysis Requirements.* This process utilizes the evaluation strategy and the capability crosswalk to identify relevant test issues, test measures, and test factors which will be used in the characterized test event. In this step, the analysis team draws upon the test goals and objectives to determine what is applicable. The analyst will develop an initial list of data requirements based on the selected measures. Data elements are the smallest and simplest units of data that impart meaningful information towards the calculation of measure responses. These should have been identified during the development of the measures, but need to be updated in this step. They will be critical for developing the DCP to ensure the collection of the required data to evaluate measure responses.

CTM 2.2.2 *Identify Additional Modeling Requirements.* The T&E methodology uses the model-test-model approach to assist in the design of SoS tests and the development of models and simulations. The team looks at previously used models and analyzes them to see how they can be utilized in the test. M&S can be useful in SoS testing. By applying analysis techniques the evaluation can focus on the most influential factors and risk areas. The use of M&S can reduce the cost and risk of testing life cycle activities. It is important to note which M&S products are readily available. By identifying necessary models and checking for availability and other key criteria, the team can identify appropriate models.

CTM 2.2.3 *Develop Test Scenario.* The test scenario is an account or synopsis of a projected course of action or events. Scenarios include information such as threat and friendly politico-military contexts and backgrounds, assumptions, operational objectives, and other planning considerations. This process creates an overarching narrative document describing a scenario reflecting a realistic LVC JME. It contains the necessary elements from the joint operational context, test concept, and the needed evaluation strategy to support the overall test plan. The test scenario describes the proposed test in joint operational terms, without regard to how the joint test scenario will be implemented. However, specific LVC requirements or constraints should be incorporated. Any operational constraints imposed by requirements such as organization behaviors and ROEs should be specified. The test scenario describes relevant operational organizations, resources, missions, and threats that will interact with the client SUT. The test scenario should specify mission objectives, blue forces, blue actions, environment conditions (for example, physical and civil conditions), threat forces, threat actions, and interactions. The general activities generated by the test scenario must be planned to allow for activities related to the identified indices of performance, and allow for collection of data consistent with test-analytic requirements.

CTM 2.3 Technical Assessment and ***CTM 2.4 Programmatic Assessment*** are not part of the evaluation thread. They are not addressed in this handbook.

CTM 3 *Plan Test.* The third step in the CTM is to develop the test design (test vignettes, test trial sets, and data collection requirements) and develop the test plan. The evaluation thread only includes ***CTM 3.1 Develop Test Design;*** however, the analyst must be available in an advisory role for CTM 3.2, CTM 3.3, CTM 3.4, and CTM 3.5. See the Action Officer's Handbook for more information on CTM 3.2 through CTM 3.5. Within ***CTM 3.1 Develop Test Design***, the analyst should ensure that the vignettes, test trials, and the data collection requirements all support the data analysis efforts. This test design step is crucial for ensuring that the proper data is generated and collected during the test event.

Figure 3-4 shows CTM 3 processes: ***CTM 3.1 Develop Test Design, CTM 3.2 Perform LVC-DE Analysis, CTM 3.3 Define Infrastructure, CTM 3.4 Coordinate Test Support,*** and ***CTM 3.5 Develop Test Plan***.

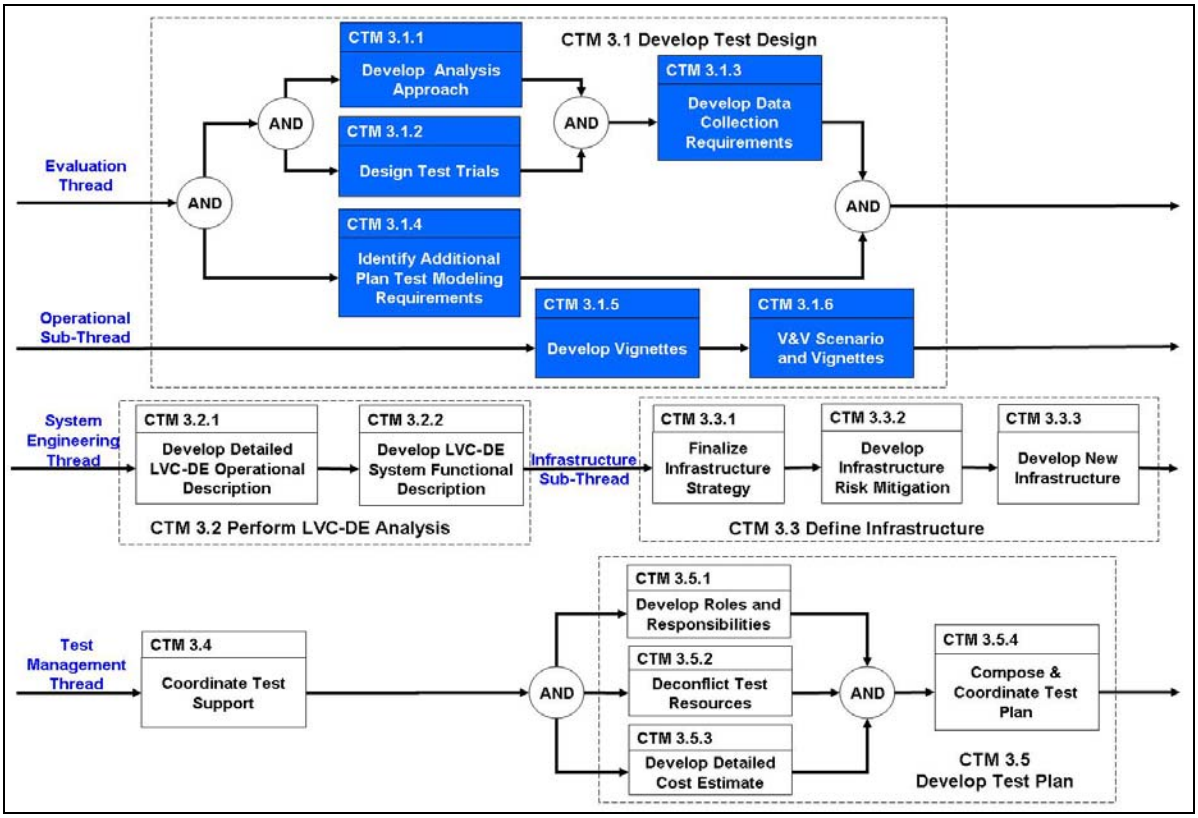

Figure 3-4. CTM 3 Plan Test

CTM 3.1, *Develop Test Design.* In this process, the test planning team analyzes the test concept, joint mission evaluation strategy (including the test scenario), and the joint operational context to develop the specifics of the test design, including test trials and vignettes, the test plan, the DAP, as well as aspects of the initial configuration management and verification and validation (V&V) plans. During this phase, details regarding the key test metrics (measures and issues), type and level of statistical and operational assessment, analytical products, and an evaluation plan are documented using the Program Introduction Document (PID) and other test documentation (for example, TES, TEMP, and others). The SOC is used to ensure technical and programmatic resources exist at the range to address test analytical support requirements. The DAP should focus on the methods and processes necessary for analyzing test data, and producing quantitative and qualitative test findings and conclusions. Figure 3-5 shows a functional flow block diagram of CTM 3.1 Develop Test Design.

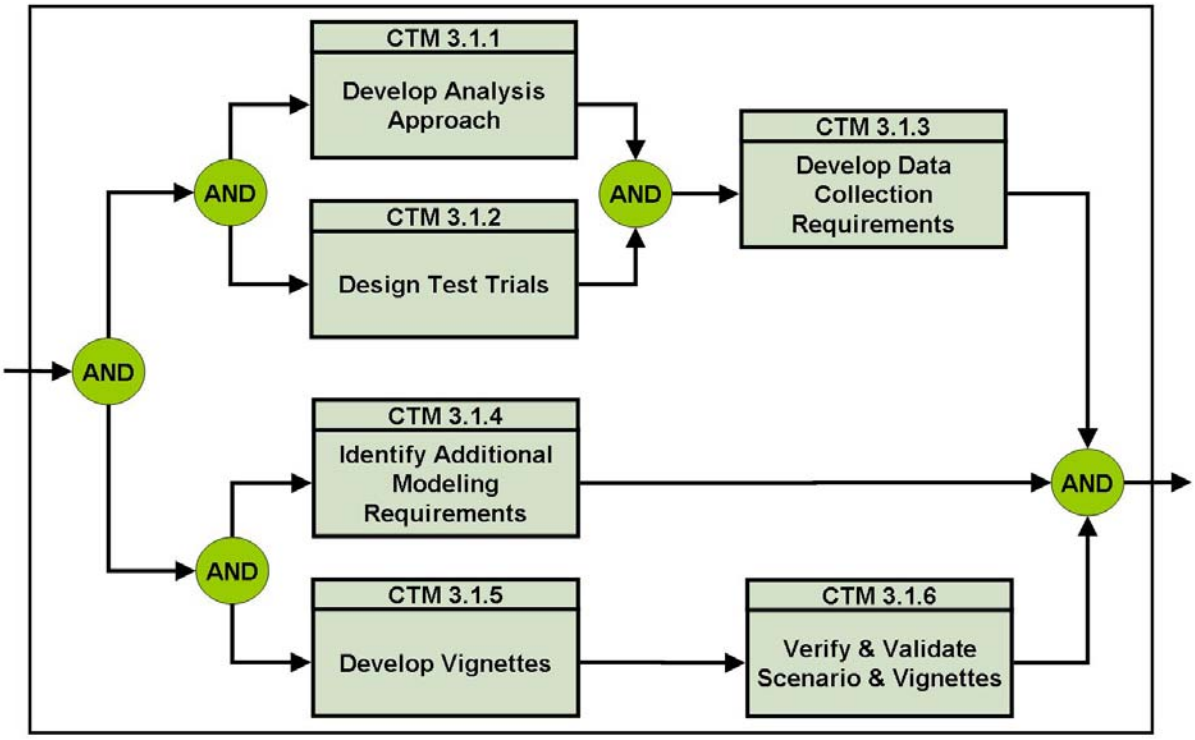

Figure 3-5. CTM 3.1 Develop Test Design

CTM 3.1.1 Develop Analysis Approach. The development of an analysis approach uses the refined evaluation strategy from CTM 2.2 to develop a test design and determine the necessary sample size. The test design must support the analysis of independent variables, the impact on mission, the task itself, as well as the dependent variables. Figure 3-6 breaks this sub-process into two subordinate sub-processes: ***CTM 3.1.1.1 Develop Experimental Test Design*** and ***CTM 3.1.1.2 Determine Test Sample Size***. The test design will be based on the number of test factors and the number of levels for each factor. A simple full factorial test design may be considered when only a handful of factors and levels are to be evaluated. However, the complexity of SoS will probably dictate a larger set of factors with multiple levels that require a much more complex test design. Annex D provides detailed information on DOE techniques that can reduce complex sets of factors to smaller efficient test designs. Analysts should consider sample size to eliminate statistical error due to outliers. The analysis approach should include recommended sample sizes to address variability.

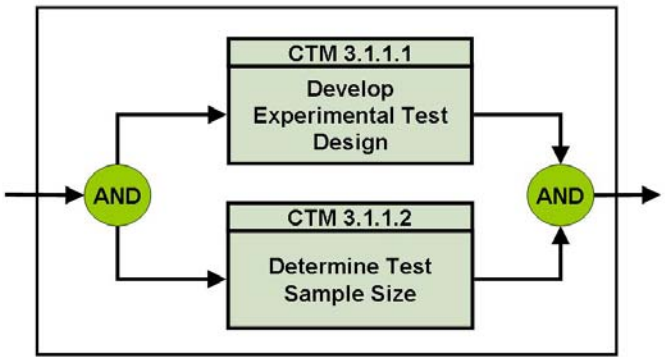

Figure 3-6. CTM 3.1.1 Develop Analysis Approach

CTM 3.1.2 Design Test Trials. After a test design is developed, a test trial matrix can be created that specifies the test design of trials incorporating levels for independent test-factor variables and dependent test-data-collection measure variables. The test trial design process identifies the best approach for the configuration of the test environment, preparation of the systems under test, management of test resources, sequencing of test trials, and definition of expected measure ranges and values. Test planners and test facility personnel should work together to determine the best way to set up the test environments, prepare the test articles, control the test resources, sequence the test trials, and predict outcome values. Budget limitations can limit the number of field tests, which forces the developer and tester to make tradeoffs to obtain the necessary test data. Computer simulation may be considered as an option.

CTM 3.1.3 Develop Data Collection Requirements. Key to any test is required data collection used to calculate the desired test measures. Requirements for data collection are threefold: the required data to be collected, the required data collection methods (for example, automated or manual), and the required data formats. When determining data collection methods, the traceability, repeatability, and reliability of each method should be considered. The data collection methodology describes an audit trail and an organized, secure means to collect the data. The data must be collected in a format conforming to the storage and retrieval procedures established in the data management approach. Data related to conditions external to the test should be collected to assist in test-vignette reconstruction and data analysis. Some examples of external conditions include inoperative support systems, inoperative data collection instrumentation, time deviations between distributed sites, unintended or inappropriate interactions between test participant and data collector, and non-standard configurations or changes that may affect the test. Data collection requirements are documented as a portion of the Data Management Plan (DMP). As part of this process, the IDRL data collection sheet is developed. This part of the IDRL includes all data elements, their collection requirements and parameters, desired units and precision, data type, the media used to collect it, and so forth.

CTM 3.1.4 Identify Additional Modeling Requirements. T&E uses the model-test-model approach to assist in the design of SoS tests and the development of models and simulations. In this process, the analysis team may take any previous models that have been used and analyze them to see how they can be used in the test. M&S can be useful in SoS testing. By applying analysis techniques, the evaluation can focus on the most influential factors and risk areas. M&S is important in reducing the cost and risk of testing life cycle activities. It is important to note which M&S products are readily available. By identifying the necessary models and checking for availability and other key criteria, the analysis team can identify appropriate models.

CTM 3.1.5 Develop Vignettes. A test vignette is a concise narrative description that illustrates and summarizes pertinent circumstances and events from a scenario. Test vignettes are subsets of the overall test scenario. Each vignette is focused on one or more test objectives from the test concept. Using an analogy, a vignette is a scene and the scenario is the movie or play. Each vignette will be comprised of sets of SoS combinations and test conditions, such as controlled variables (or factors) under which the test systems and participants will be subjected for a test trial or set of test trials to measure SoS performance and JMe. When developing the vignettes, it is important to reference ***CTM 1.2.2 Develop Test Scenario***, as it has an initial outline of the individual events that helped to make up the test-scenario portion of the PID. The vignette has test-related evaluation and configuration constraints relating to the evaluation strategy's factors and controls. The vignettes should identify all test players, the time sequence of events, and whether they can support one or more test trials. The test vignette(s) will also identify important operational context information that is not in the analysis plan to ensure that all key test indices of performance are addressed and collected.

CTM 3.1.6 Verify & Validate Scenario & Vignettes. The scenario and vignettes must be verified to be an accurate conceptual representation of the real world JME. In addition, they must be validated to meet the intended requirements of the T&E. The scenario and vignettes must satisfy the requirements of the evaluation strategy in testing the SoS ability to perform a set of tasks under a set of conditions in order to achieve a mission-desired effect. The scenario and vignettes must be sufficient to meet the data collection requirements established in CTM 3.1.3. The primary goals for verifying the scenarios and vignettes are to demonstrate that they fully cover the verified test goals, objectives and approach, the JOC-T description and, if required, to indicate the need for any corrective actions. The scenarios and vignettes outline the LVC executions and if they do not fully cover the intended use then achieving the test goals, objectives and approach could be endangered. Validation confirms the scenario and vignettes are accurate with regard to the JOC-T.

CTM 3.2 Perform LVC-DE Analysis. The test planners and engineers use system engineering best practices to develop an LVC distributed environment (LVC-DE) functional description, which is an implementation-independent representation of the test functionality required to create the JME for the test. More information on this process is available in the Action Officer's Handbook.

CTM 3.3 Define Infrastructure. In CTM 3.3, the CTM 3.2 LVC-DE functional description is coupled with CTM 3.1 Test Design artifacts to determine the infrastructure team's early estimate of LVC implementation of the JME. More information on this process is available in the Action Officer's Handbook.

CTM 3.4 Coordinate Test Support. Since testing SoS in a JME is likely to involve multiple test facilities and ranges, this process ensures that all requirements, both physical and virtual, are deconflicted and resourced. More information on this process is available in the Action Officer's Handbook.

CTM 3.5 Develop Test Plan. This process synthesizes operational, technical, management, and support functional areas of the test planning phase into an overall, coordinated test plan. Elements of the test plan include the DAP, vignette and trial matrix, LVC-DE functional design, and test-support plan. Administration and management (test organization, test control, and test readiness), test schedule, and cost-estimate descriptions are further coordinated and incorporated into the test plan. The DAP should focus on the methods and procedures necessary for analyzing test data, and producing quantitative and qualitative test findings and conclusions. More information on this process is available in the Action Officer's Handbook.

3.2 Capability Evaluation Metamodel (CEM)

Figure 3-7 shows the CEM representation of ***CTM 2 Characterize Test***. Along the CTM 2/3 Characterize & Plan Test axis, the metamodel shows the overall test goal decomposed in the test objectives. The test objectives focus on particular concepts developed as part of the ***CTM 1.2 Develop Evaluation Strategy*** axis; each test objective should support the CCI and focus on a subset of the elements of the capability crosswalk. The test objectives, in combination with the JOC-T concepts developed as part of CTM 1.3, are the basis for the development of the test scenario – a key product of this process.

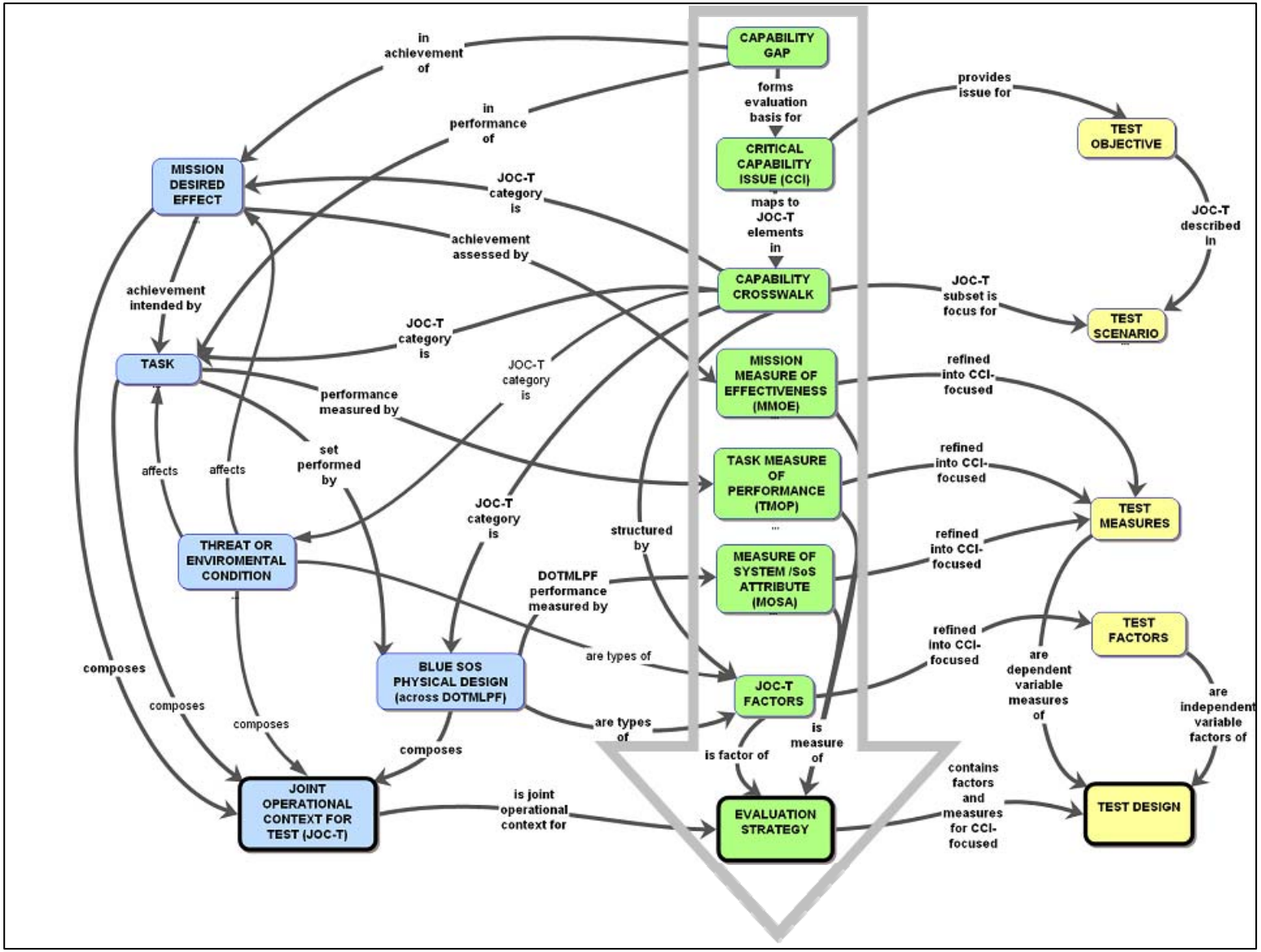

Figure 3-7. CEM Representation of CTM 2 Characterize Test

Figure 3-8 shows the ***CTM 3 Plan Test*** relational concepts in this process reflected in the CEM. A DOE approach is used in the CEM to frame capability test designs in terms of independent variables (the causal conditions) and the dependent variables (the effects). CEM independent variables are manipulated factors in the test whose presence or degree affects change in dependent variables. There are three independent variable treatment dimensions in a CEM test design: joint mission(s) and task(s), threat and environmental conditions, and SoS configuration options across DOTMLPF resources. CEM dependent variables are response measures, whose changes are caused by the presence, or degree of independent variables in the test. Dependent variables are measured for increases and decreases in mission effectiveness across Mission MOE, Task MOPs, and MOSAs. The test design is a key element of the DAP, produced in ***CTM 3.4 Develop Test Plan***. It includes a trial matrix that specifies the test design of vignette trials and incorporates levels for independent test factor variables and dependent test data collection measure variables.

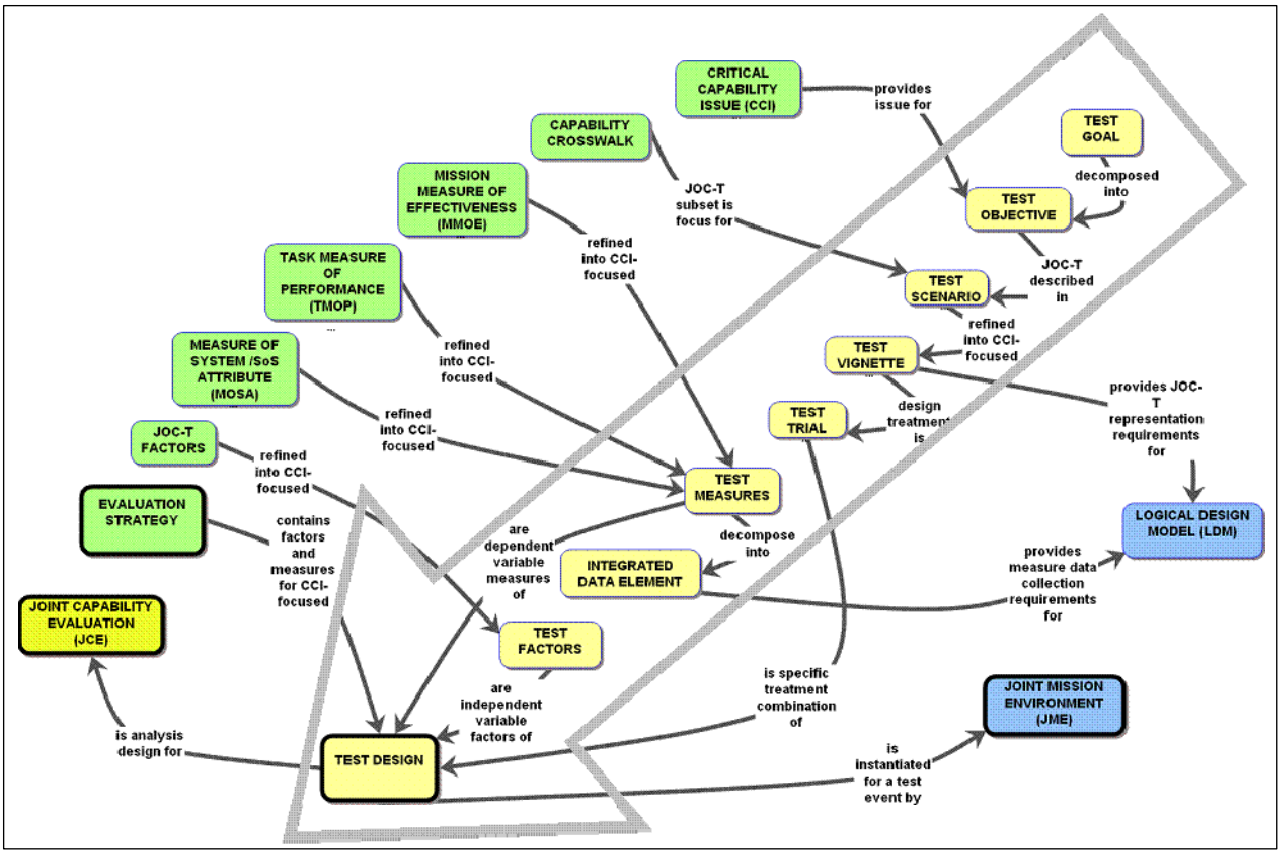

Figure 3-8. CEM Representation of CTM 3 Plan Test

3.3 Instructions for CTM 2.1 Develop Test Concept

This section described the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 2.1.

(1) **Purpose**: The analyst must evaluate available joint test requirements and the relevant joint operational context to develop a risk-mitigated approach to creating the necessary test environment. The test concept involves activities to establish an overall test goal, test objectives, and test approach.

(2) **Discussion**: The test planning team establishes an overall test goal that narrows the test to a specific set of joint system/SoS capabilities and contributions to joint capability. In addition, the test planning team will establish test objectives, which can be viewed as the customer's questions that will be tested in the joint environment. The test approach is developed to provide an initial test overview identifying when, where, and notionally how the test will be executed. The test approach describes an overall scope of the test.

(3) **Tools and Techniques**: The T&E strategy, capability crosswalk, and the JOC-T will provide the basis for developing the test concept. There should only be one test goal, but there can be several test objectives. The development of the test concept should be closely coordinated with the test manager and addressed with the PMs.

(4) **Inputs**: Figure 3-9 identifies sources of information desired for executing this section of the CTM. Described below are those required inputs. The remaining sources are optional.

Recommended Input Info/Sources		Products	Example
2.1 Develop Test Concept			
	❑	Test Concept	
2.1.1 Establish Overall Test Goal			
▪ Test and Evaluation Strategy ▪ Test and Evaluation Master Plan ▪ Other Test Plans ▪ Initial Capabilities Documents ▪ Capability Development Documents ▪ Capability Production Documents ▪ Joint Capability Areas ▪ DOTMLPF Change Requests	❑	a. Test Goal	
2.1.2 Establish Test Objectives			
▪ Test Goal ▪ Test and Evaluation Strategy	❑	a. Test Objectives	
2.1.3 Develop Test Approach			
▪ Test Objectives	❑	a. Test Approach	

Figure 3-9. CTM 2.1 Develop Test Concept Checklist

Joint Capability Documents. The Joint Capability Documents refer to the JCIDS Initial Capabilities Document (ICD), the Capability Development Document (CDD), and the Capability Production Document (CPD). This set of documents identifies a capability gap and the proposed SoS to fill the gap. Specific information is in the JCIDS instruction CJCSI 3170.01.[25]

Joint Capability Areas (JCA). The JCAs are collections of similar DoD activities functionally grouped to support capability analysis, strategy development, investment decision making, capability portfolio management, and capabilities-based force development and operational planning. The capability gap should be categorized into a JCA activity as a shortfall.

DOTMLPF Change Request (DCR). "The joint DCR defines the implementation of recommendations to change joint DOTMLPF and policy from USJFCOM or other sponsors of joint experimentation…, joint testing, and evaluation… activities."[26]

(5) **Actions**: The analyst will work with the test manager and test planners to develop the test concept.

Review required inputs. Review the required inputs for descriptions of the SoS, the evaluation strategy, and the test issues.

Develop the test goal. Assist the test planners with the drafting of a test goal. Ensure the test goal meets the needs of the evaluation strategy and conforms to the capability crosswalk and test issues.

Develop the test objectives. Assist the test planners with the drafting of the test objectives. Ensure the test objectives meet the needs of the evaluation strategy and conform to the capability crosswalk and test issues. If needed, map the test issues to the test objectives to ensure continuity.

Develop the test approach. Assist the test planners with the drafting of the test approach. Ensure the test approach addresses the appropriate test issues and evaluation strategy. Look for discrepancies or voids in the test approach that will hinder data collection efforts or mission, task, and SoS/SUT analysis.

(6) **Products**: The output from this process is an overall test concept. Although the analyst is not the lead for developing the test concept, the analyst should participate and ensure the evaluation requirements are met. The test concept will ultimately be incorporated into the Test Plan (TP) and the DAP.

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[25] CJCSI 3170.01F, Joint Capabilities Integration and Development System, 1 May 2007.

[26] Ibid.

3.4 Instructions for CTM 2.2 Refine the Evaluation Strategy

This section describes the methods and processes the analyst uses to prepare and execute the evaluation thread in CTM 2.2.

(1) **Purpose**: The analyst must select from the overall capability evaluation strategy those issues, measures, and data elements that can be applied to the test event. Based on the test goal and objectives, the selected sections will be used as a refined test event evaluation strategy.

(2) **Discussion**: Using the evaluation strategy formed in the TES, the analyst selects relevant sections of the initial evaluation strategy for use in the characterized test. The test goal, objectives, and approach are the basis to refine the general test issues, CCIs and COIs, and the evaluation strategy framework. The refined strategy will include relevant mission, task, and SoS components. The refined strategy must have at least one Mission MOE, at least one task and associated Task MOP, and identified systems that compose the overall SoS or a major component of the SoS. The refined evaluation strategy must identify SoS test factors and conditional factors. This refined strategy will allow for the identification of data elements, potential modeling requirements, and the identification of test scenario(s).

(3) **Tools and Techniques**: The capability crosswalk matrix, mission mapping, task-to-mission mapping, and system attribute mapping will provide the necessary tools to refine the strategy and map the applicable sub-set of the capability evaluation strategy.

(4) **Inputs**: Figure 3-10 identifies sources of information desired for executing this section of the CTM. Additional inputs (not previously described) are described below; the remaining sources not described are considered optional.

System of Systems Description. The systems description and SoS description are developed to describe the key features and subsystems, and hardware and software for the capability. Since there may be several SoS configurations, each must be described with those factors that will be evaluated in the test.

Recommended Input Info/Sources	Products		Example
2.2 Refine Evaluation Strategy			
	❑	Refined Evaluation Strategy	
2.2.1 Develop Initial Data Analysis Requirements			
▪ Test and Evaluation Strategy ▪ Test and Evaluation Master Plan ▪ Other Test Plans ▪ Initial Capabilities Documents, Capability Development Documents, and Capability Production Documents ▪ Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities (DOTMLPF) Change Request ▪ System of Systems/System Description ▪ Critical Capability Issues (CCI)/Critical Operational Issues (COI) ▪ Joint Operational Context for Test (JOC-T)	❑	a. Capability evaluation subset	
	❑	(1) Test CCI/COI	
	❑	(2) Test factors	
	❑	(3) Test measures	
	❑	(4) Test data elements	
2.2.2 Identify Additional Modeling Requirements			
▪ Known Modeling Requirements	❑	a. Additional Modeling Requirements	
2.2.3 Develop Test Scenario			
▪ Capability Evaluation Subsets o Factors o Measures o Data Elements ▪ Critical Capability Issues (CCI)/Critical Operational Issues (COI) ▪ Joint Operational Context for Test (JOC-T)	❑	a. Test Scenario	

Figure 3-10. CTM 2.2 Refine Evaluation Strategy Checklist

(5) **Actions**: The analyst will assist the test manager and test planners in the test strategy refinement.

Develop initial data analysis requirements. The analyst will develop an initial list of data elements that must be collected in the test event. This will require a refinement of the capability evaluation strategy as follows:

- ***Determine Applicable CCI and COI***. The analyst will list which CCIs and COIs are applied to the test event, based on the test goal and objectives developed in CTM 2.1.

- ***Determine applicable test factors***. The analyst will determine which test factors can be explored as a part of the test event. The test factors may be either SoS configuration factors or conditional (threat or environment) factors. The analyst will list the test factors and levels to explore.

- ***Determine applicable test measures***. The analyst will determine which capability measures can be addressed in the test event. This should be based on the chosen CCIs and COIs. The CCIs dictate what mission-desired effects and Mission MOEs will be tested. The CCIs also dictate what tasks and Task MOPs will be tested. The CCIs and COIs dictate which SoS and system attributes to test.

- ***Determine applicable test data elements***. The analyst will list the data elements as a result of the applicable test measures. This should be captured in a refined IDRL that identifies each data element and metadata element requirement linking data elements for future analysis.

Identify additional modeling requirements. Create a list of modeling requirements supporting data elements collection. For example, if threat data is required, M&S may be required providing threat outcomes based on friendly SoS interactions with the threat environment. The test system engineers should help develop this list. Alternatives must be considered and listed in order to reduce risk to unavailable modeling resources. The additional modeling requirements help to form the basis for determining the LVC-DE.

Develop test scenario(s). The analyst will support the test planners in developing test scenario(s). They are described as a brief description of the course of actions that must occur during the test event. The test scenario(s) should describe how the blue forces, threat forces, and environment act/interact as the test event proceeds. More than one test scenario may be required depending on the test factors. Any relevant additional detail on the operational units, resources, missions, or threats should also be described. Specific ROEs, standard operating procedures, or task threads followed during the test should also be described. The analyst should capture any assumptions made during the development of the test scenario.

(6) **Products**: The output of this process is a refined evaluation strategy that will drive the planning, execution, and analysis of the test event. The evaluation strategy will be documented in the event test plan and in the DAP. The analyst is responsible for DAP development and will ensure the evaluation strategy is captured there. The evaluation strategy will include:

Complete list of test factors and levels for each. Includes SoS factors as well as conditional (threat and environmental) factors.

List of mission-desired effects and Mission MOE.

List of joint and Service tasks and associated Task MOP.

List of data elements and metadata requirements. An IDRL will be developed to contain these requirements. See annex F (IDRL) for examples and descriptions.

3.5 Instructions for CTM 3.1 Develop Test Design

This section describes the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 3.1. Segments of this section will refer to the DOE annex D for detailed information.

(1) **Purpose**: The analyst must develop the test design that will drive the entire evaluation process for the test event. This includes the development of test trials, vignettes, and data collection requirements.

(2) **Discussion**: This process analyzes the test concept, test event evaluation strategy (including the test scenario), and the joint operational context to develop the specifics of the test design including test trials, test vignettes, data collection requirements, as well as aspects of the initial configuration management and V&V plans. A trial matrix is created that specifies the test design of vignette trials incorporating levels for independent test factor variables and dependent test data collection measure variables. Test planners and test facility personnel should work together to determine the best way to set up the test environments, prepare the test articles, control the test resources, sequence the test trials, and predict outcome values. Budget limitations can limit the number of field tests, as field tests are usually the most expensive per trial. The cost of test trials forces the developer and tester to make tradeoffs to obtain the necessary test data; an option is the use of computer simulation. Test planners and systems engineers should develop PID and SOC documents in the test design process. The analyst will continue to develop the DAP for the test and update the IDRL and data collection requirements. The DAP should focus on the methods and processes necessary for analyzing test data, and producing quantitative and qualitative test findings and conclusions. The data collection requirements will form a basis for the DCP.

(3) **Tools and Techniques**: The test design requires development of a DOE that will form the basis for a test trial matrix. Many text books, technical articles, and software packages provide tools and techniques for DOEs. Simple designs may not require much support, whereas complex designs will require sophisticated tools and techniques. Annex D (DOE) provides the analyst with different DOE options that support simplifying complex designs into more manageable test trial matrices. There are software packages that will allow the analyst to link DOE and analysis requirements to simulations within a computing cluster or across multiple processors. These same tools may be useful for test characterization and even test execution in the LVC-DE. Since these tools are designed to interoperate with particular, pre-identified models, the analysis team must ensure that they account for such modifications early if they plan to use such a tool.

(4) **Inputs**: Figure 3-11 identifies recommended sources of information for executing this section of the CTM.

Recommended Input Info/Sources		Products	Example
3.1 Develop Test Design			
	☐	a. Test Design	Annex D Fig. D-10
3.1.1 Develop Analysis Approach			
▪ Analytical model capabilities ▪ Test measures and data elements ▪ Efficient test trial design of experiment	❑	a. Analytical approach	
3.1.2 Design Test Trials			
▪ Vignettes	❑	a. Test trial matrix	Fig. 3-12
3.1.3 Develop Data Collection Requirements			
▪ Test Trials	❑	a. Integrated Data Requirements List	Fig. 3-13
3.1.4 Identify Additional Plan Test Modeling Requirements			
▪ Vignettes ▪ Test trials ▪ Integrated Data Requirements List	❑	a. Analytic Model Capabilities	
3.1.5 Develop Vignettes			
▪ Test scenarios ▪ Test trials	❑	a. Vignettes	
3.1.6 Verify and Validate Scenario and Vignettes			
▪ Test scenario ▪ Vignettes	❑ ❑	a. Verified and validated test scenario b. Verified and validated test vignettes	

Figure 3-11. CTM 3.1 Develop Test Design Checklist

(5) **Actions**: The analyst will lead and support the process to develop the test design.

Develop an analysis approach. The analyst will use the refined evaluation strategy from CTM 2.2 to develop an analysis approach that will support analysis of test factors (independent variables) impact on mission, task, and SoS measures (dependent variables).

- ***Develop experimental test design.*** The analyst will develop an experimental test design based on the number of test factors and levels for each factor. Annex D (DOE) provides detailed information on DOE techniques that can reduce complex sets of factors to smaller efficient test designs.

- ***Determine test sample size.*** The analyst will determine optimal sample size that will meet statistical data analysis requirements. Alternative approaches or tradeoffs may need to be considered as resources may limit the ability to meet sample size requirements.

Design test trials. The analyst will develop a test trial matrix that meets the needs of the experimental test design and sample size requirements. The test trial matrix should identify the test design that incorporates levels for independent test factor variables and dependent test data collection measure variables. It should also specify the sequence the test trials that reduces test design errors.

Develop data collection requirements. The analyst will finalize the IDRL data collection sheet to document the required data to be collected. It should include not only what data is to be collected, but who, when, where, and how the data will be collected. The data collection sheet of the IDRL should include the required data-collection methods (e.g., automated or manual), the required data formats, what trials the data is collected, where the data is collected, and who has responsibility for the data.

Identify additional plan test modeling requirements. The analyst will identify additional pre-event modeling requirements with the intent of reducing the test design to focus on the most influential factors and risk areas. This may be required to reduce the cost and risk of testing lifecycle activities. Annex C (Exploratory Analysis) provides detailed information on exploratory analysis activities that can direct this process.

Develop vignettes. The analyst will support the test planners in the identification of test vignettes, if required. Each vignette is a set or thread of event activities conducted against a test configuration which can have multiple factors and levels. The analyst will incorporate test vignettes in the data collection requirements when they impact collection of data elements.

Verify and validate scenario and vignettes. The analyst will support the test planners in verifying and validating the scenario and vignettes' ability to cover fully the test goal, test objectives, and the test approach. The analyst's primary concern is that the scenario and vignettes will support the evaluation strategy and data collection requirements. Therefore, the analyst will identify deficiencies in the scenario and vignettes and address the issues with the test planners and test manager.

(6) **Products**: The output of this process is a test design that will support the evaluation strategy requirements. All the products developed in this process are discussed below but

should be included in the development of a DAP. It is the responsibility of the analyst to draft and complete this DAP. Specific products are:

Test trial matrix. The test trial matrix documents the experimental test design that incorporates levels for independent test factor variables and dependent test data collection measure variables. The test trial matrix should also include requirements for multiple test trials to meet sampling requirements. Figure 3-12 provides an example.

				Initial Airspace Allocation			
				CAS		Fire Support	
				Small ACV	Large ACV	Small ACV	Large ACV
Third Party Source Terminal Weapon Control	Second Aircraft	Weapon Order	CAS First	Trial 1			Trial 7
			Fire Support First		Trial 5	Trial 3	
	JTAC	Weapon Order	CAS First		Trial 6	Trial 4	
			Fire Support First	Trial 2			Trial 8

Figure 3-12. Test Trial Matrix

IDRL data reduction sheet. The IDRL data reduction sheet will document the required data to be collected. It should include not only what data is to be collected, but who, when, where, and how the data will be collected. The data reduction sheet of the IDRL should include the required data-collection methods (for example, automated or manual), the required data formats, what trials the data is collected, where the data is collected, and who has responsibility for the data. See Figure 3-13 for an example.

Measure	CCI COI	Scale Units	Measure	Parent Relation	Criteria	Data Element	Data Fields
MMOE-1	CCI-1	Percent	Threat Systems Combat Ineffectiveness	Mission Desired Effect of neutralized forces	80%		
		Number				Count threat units in JOA at test run start time	For each test run: (Test Trial #, Test run #, Threat Unit Count at Start)
		Number				Count threat units ineffective in JOA at test run end time	For each test run: (Test Trial #, Test run #, Count Threat Units Ineffective at end time)
TMOP-1	CCI-1	Time	To C2 Indirect Fires (JCAS. JFIRES) missions	UJTL - TA 5.x Execute Immediate Deconfliction	10 min		
		Time				Start time when Indirect Fires (IF) request enters C2 (Decide & Deconflict - see Mission Task Flow Diagram)	For each IF request in a test run (IF ID #, Type {JFIRES,JCAS,CCA}, Decide start time)
		Time				End time when Indirect Fires (IF) request exits C2 (Decide & Deconficit - see Mission Task Flow Diagram)	For each IF request in a test run (IF ID #, Type {JFIRES,JCAS,CCA}, Deconfliction end time)
MOSA-1	CCI-2	Time	Speed of Decision (C2 time minus the Deconfliction time)	Indirect Fires C2 SoS	5 min		
		Time				Start time when IF request accepted (Accepted C2 box - see Mission Task Flow Diagram)	For each IF request in a test run (IF ID #, Type {JFIRES,JCAS,CCA}, Decide start time)
		Time				End time when IF request exits request evaluated (Evaluate C2 box - see Mission Task Flow Diagram)	For each IF request in a test run (IF ID #, Type {JFIRES,JCAS,CCA}, Decide end time)
MOE	COI-1	Percent	Detection at max range	NLOS-LS	90%		
		Number				Count of detection attempts	For each test run: (Test Trial #, Test run #, Weapon ID #, Detection #)
		Number				Count of successful detections	For each test run: (Test Trial #, Test run #, Weapon ID #, Detection #, Detection status)
MOS	COI-1	Percent	Weapon reliability	NLOS-LS	99%		
		Number				Count of weapon fires	For each test run: (Test Trial #, Test run #, Weapon ID #, Fires #, Fires Status)
		Number				Count of weapon mis-fires	For each test run: (Test Trial #, Test run #, Weapon ID #, Fires #, Fires Status)

Figure 3-13. IDRL Data Reduction Sheet

Data Analysis Plan (DAP). The DAP provides detailed procedures for the collection, reduction, collation, and analysis of data gathered to support determination of operational effectiveness and suitability of a system/SoS. At this point in the process, the DAP should be a complete draft ready to be aligned with the test plan. The DAP is designed to provide the specifics for the analysis of operational effectiveness and suitability of the system and SoS. The DAP should include all the products developed by the analyst in CTM steps 1, 2, and 3 to document the components of the evaluation strategy and the test data requirements.

4
IMPLEMENT LVC-DE

This chapter addresses the evaluation thread for CTM 4 Implement LVC-DE. It focuses on the requirements to construct a logical and physical design of the test concept and the test event evaluation strategy. Section 4.1 provides a description of the steps and processes (and sub-processes) that are parts of the evaluation thread. Follow-on sections in the chapter provide the detailed instructions to guide the analyst in conducting the evaluation methods and processes.

4.1 Capability Test Methodology (CTM) and Processes for CTM 4

The fourth step in the CTM is to implement the LVC-DE. These processes, shown in Figure 4-1, include designing LVC-DE configurations, building and configuring LVC-DE components, encoding vignettes, and integration of the LVC-DE. The test plan, which includes the LVC-DE functional design, vignettes, DAP, and the test support plan, is the major input to this step. The design of the LVC-DE configuration is of concern to the analyst, even though it is not part of the evaluation thread. This handbook provides a short description of these processes. For more detailed information, see the Action Officer's Handbook. Figure 4-1 shows two sub-processes, CTM 4.1.1 and CTM 4.1.3, under CTM 4.1 that will be the focus of discussion in this chapter.

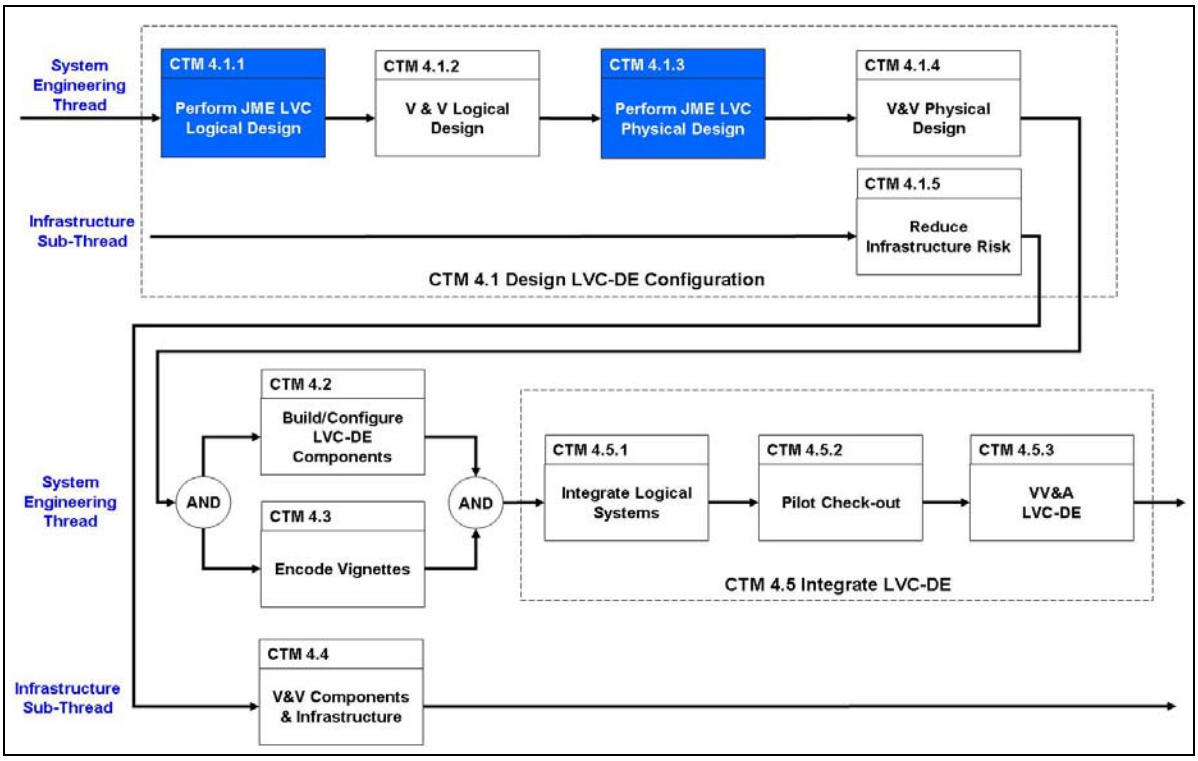

Figure 4-1. CTM 4 Implement LVC-DE

The CEM components of the LVC-DE are the JME Foundation Model (JFM), the Logical Design Model (LDM), the Physical Design Model (PDM), the PDM transformation, the JME

interface, and the actual JME. Figure 4-2 shows the components and the relationships of the LVC-DE axis of the CEM, which correspond to CTM 4.

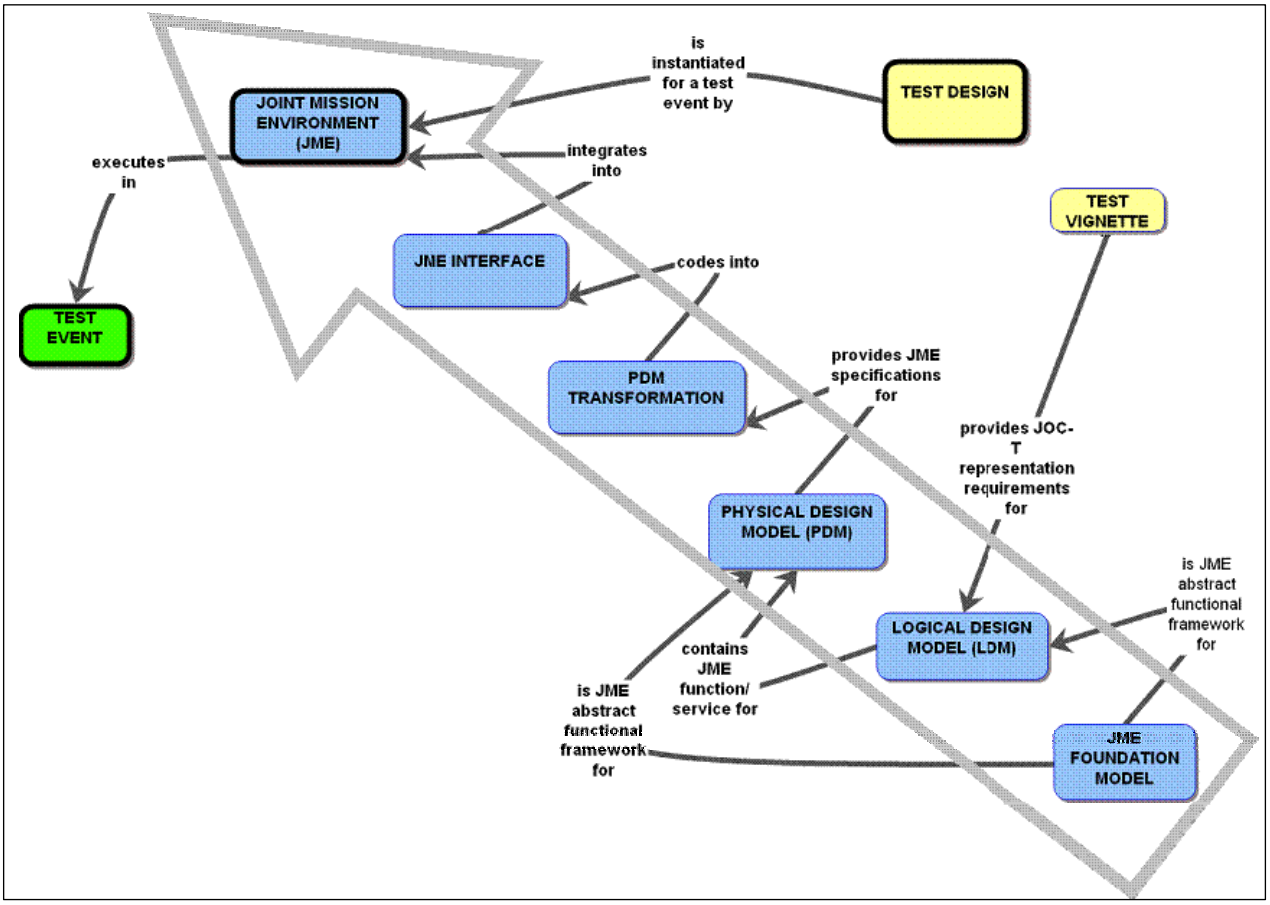

Figure 4-2. LVC-DE Axis of the CEM

CTM 4.1 *Design LVC-DE Configuration.* The LVC-DE configuration uses systems engineering best practice to develop the LVC-DE design. This LVC-DE design synthesis develops logical and physical design specifications (LVC platforms, LVC environment, test control, terrain, weather, databases, data collection, test infrastructure, system hardware, software elements, and so forth) capable of performing the required JME test functions within the limits of the functional parameters prescribed in the functional design. This analysis also includes the planning, conduct, and reporting of a test infrastructure characterization and verification for networks and middleware.

CTM 4.1.1 *Perform JME LVC Logical Design.* The logical design is the conceptual model for the test configuration. It uses the LVC-DE functional description to quantify test objectives and tasks within a logical LVC-DE configuration. The logical design also identifies the LVC framework and standards needed to achieve the test objectives and tasks independent of system/SoS solutions. It uses the test plan, analysis plan, evaluation strategy, SOC, PID, LVC-DE functional description, and the JME as input. The output results in a

JME LVC logical design document containing the relative DoDAF products and descriptions to be reviewed and used in the follow-on physical design.

CTM 4.1.3 *Perform LVC Physical Design.* The physical design instantiates the logical design to constitute the LVC-DE, with the identification of test sites, test instruments, and test infrastructure. It will specify hardware; network topologies; middleware; data layer instantiations in hardware and software; communications gateways; and the actual live, virtual, and constructive components in the JME depicting communication gateways and actual information flows. The physical design should also include the object models and interfaces used between applications and in the middleware. Ultimately, it assesses gaps and shortfalls in the test capabilities and identifies alternative resources to accomplish the full-range of functions identified in the logical design.

4.2 Instructions for CTM 4.1 Design LVC-DE Configuration

This section described the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 4.1.

(1) **Purpose**: The analyst must ensure the logical and physical designs can support the data collection requirements of the IDRL with the identification of data collection points in the physical design that will meet the requirements of the analysis plan. This process is crucial for a successful evaluation program.

(2) **Discussion**: The test event systems engineers (technical personnel) are responsible for developing the logical and physical designs of the test event. The analyst ensures that the physical design supports the analysis plan with data collection points built into the design that supports collection of all data elements required in the IDRL. This requires a verification of the IDRL requirements through the logical and physical designs by mapping to the OV-7 and SV-11 respectively. A clear understanding of the physical design is required by the analyst to include how each task thread is instantiated in the physical design and the sequence of events that occurs in those threads. If the logical and physical designs are properly documented, this understanding may be obtained by studying the DoDAF operational and system views developed in the process.

In the critical design review (CDR) the IDRL to physical design mapping should be verified. The IDRL should be mapped through the physical design to the physical data schema and actual databases used in the LVC-DE (mapping done to the OV-7 in the logical design at the PDR and to the SV-11 in the physical design at the CDR).

(3) **Tools and Techniques**: The recommended technique for conducting this section of the CTM is to map the data collection requirements found in the analysis plan, specifically the IDRL, to the physical design documents, specifically the DoDAF products. The mapping process should be documented in both the IDRL spreadsheet and the DoDAF products.

(4) **Inputs**: Figure 4-3 identifies sources of information that are desired for executing this section of the CTM. Described below are those required inputs. The remaining sources are optional and may help with the process.

Recommended Input Info/Sources	Products	
4.1 Design LVC-DE Configuration		
	❑	LVC-DE Configuration
4.1.1 Perform JME LVC Logical Design		
▪ Joint Operational Context for Test ▪ DoDAF Products (AV-2, TV-1, OV-1, 2, 4, 5, 6c, 7, SV-1, 4a, 4b, 6, 10c	❑	JME LVC-DE Logical Design
4.1.3 Perform JME LVC Physical Design		
▪ JME LVC-DE Logical Design ▪ DoDAF Products (AV-2, TV-1, OV-1, 2, 4, 5, 6c, 7, SV-1, 4a, 4b, 6, 10c ▪ Data Analysis Plan ▪ Vignettes ▪ V&V Plan (Initial)	❑	JME LVC-DE Physical Design
	❑	IDRL – Physical Design mapping

Figure 4-3. CTM 4.1 Design LVC-DE Configuration Checklist

Joint Operational Context for Test (JOC-T). The JOC-T describes capability concepts and relationships, as defined in JCIDS, including mission, task, condition, and SoS. JOC-T mission aspects include the mission statement, mission-desired effects, and mission end state. JOC-T task aspects include mission CONOPS, blue force UJTL-based JMETs; Service tasks; and tactics, techniques, and procedures (TTP). JOC-T condition aspects include threat conditions (for example, threat actions, threat order of battle, threat C2 structure, threat systems, threat force laydown) and environmental conditions (for example, physical and civil environment). JOC-T blue SoS aspects include JCA operational functions and DOTMLPF materiel and non-materiel resource descriptions across DOTMLPF. The JOC-T may include DoDAF artifacts AV-2, OV-1, OV-5, SV-4a/b, SV-6, SV-10c, and TV-1.

Data Analysis Plan (DAP). The DAP provides detailed procedures for the collection, reduction, collation, and analysis of data gathered to support determination of operational effectiveness and suitability of a system/SoS. The DAP aligns with the test plan, contributing to a successful test, and is a planning tool to ensure procedures are in place for assessing data collection upon completion of test execution. The

DAP is designed to provide the specifics for the analysis of operational and suitability of a system/SoS. The DAP should be completed before the test event begins to ensure the needs of various system/SoS customers and that the resources are available to complete the data analysis. The DAP should include the purpose of the data analysis, data sources (including a description and any limitations), key variables to be used, and the data analysis methods. The capability manager should review the plan to ensure that the proposed data analysis will answer relevant questions. Data analysis experts should review the plan to ensure that appropriate data and methods will be used and the DAP should be approved by the capability manager.

Vignettes. Test vignettes are subsets of the overall test scenario. Each vignette is focused on one or more test objectives from the test concept. Using an analogy, a vignette is a scene and the scenario is the movie or play. Each vignette will be comprised of sets of systems/SoS combinations and test conditions, that is, controlled variables (or factors), under which the test systems/SoS and participants will be subjected for a test trial or set of test trials to measure system/SoS performance and JMe.

(5) **Actions**: The analyst will provide support to the systems engineers in the design of the LVC-DE.

Gather required inputs. Provide the draft DAP and any other supporting documentation that identifies data elements and data collection requirements.

Assist in development of the logical design. Assess how the logical design instantiates the JME. Verify IDRL requirements in the OV-7.

Assist in mapping data requirements to physical design. Assess the physical designs ability to support data collection. Assist system engineers with mapping data collection points to the DoDAF system views. Verify IDRL requirements in the system view documents (SV-10c, SV-11). See Figure 4-4 for an example.

Document data collection in the IDRL. Update the IDRL with data requirements. Evaluate for completeness and risk.

Participate in design reviews. Participate in the preliminary design review (PDR) and the CDR to address analytical requirements in the respective logical and physical designs.

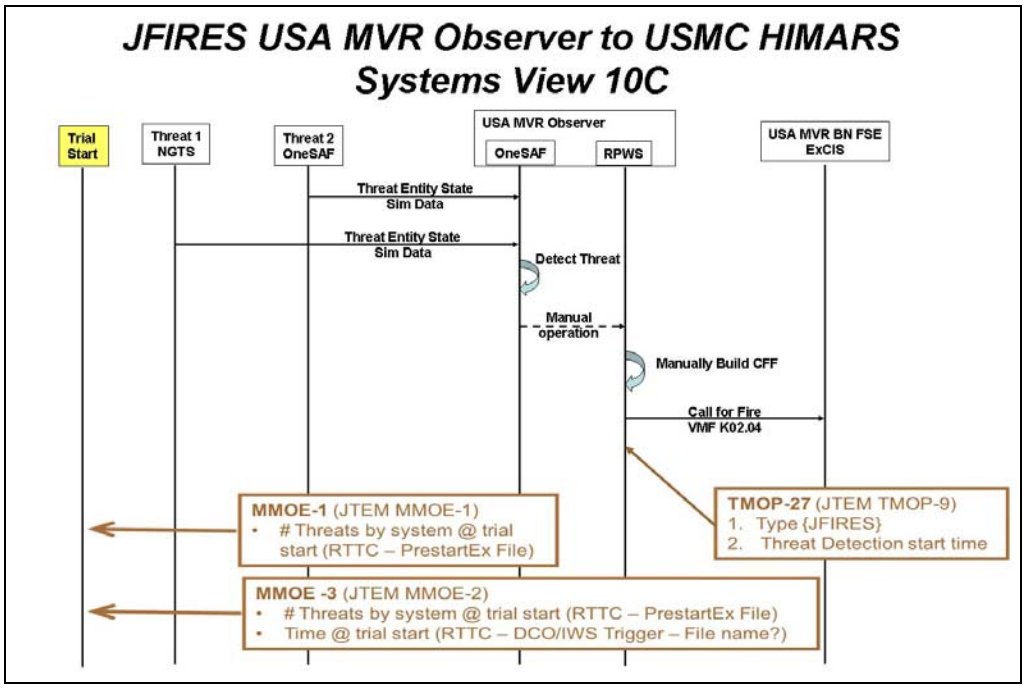

Figure 4-4. Example SV-10C with Identified Data Collection Points

(6) **<u>Outputs</u>**: The completion of the IDRL will be the output for this section of the analysis process. The analyst will complete the IDRL with applicable fields that document how each required data element is collected and the data collection point. See Figure 4-5 for an example. The analyst shall identify any deficiencies and possible areas of risk that will hinder the data collection process.

Data Element	Data Fields	Possible Values	Amplifying information	Data Structure	Data Format	Collection Rate	Test Run	Data Source	Data Media	Instru-mentation	Output File Structure
Test Trial											
	Test Trial ID #	1 to 4	Identifies the Test Trial	Integer	1,2,3, ...	Before test event	All	Controller	Manual	None	
Test Run											
	Test Run ID #	1 to 4	Identifies the Test	Integer	1,2,3, ...	Each Test Run	All	Controller	Manual	None	
	Test Run Start time	0	Test run start at time 1	minutes	xxx.xx	Each Test run	All	RTTC	Electronic	DCO/IWS Trigger	
	Threat Count at Start Time		Count of threat units in the JOA at test run start time	Integer	1,2,3, ...	Each Test run	All	RTTC	Electronic	Prestart File	
Indirect Fires Request											
	ID Number	1,2,3, ...	Sequential ID number for each indirect fires (JCAS/JFIRES request	Integer	1,2,3, ...	At creation of request	All	RPWS	Electronic message	VMF K02.05	
	Type	JCAS, JFIRES, CCA	Type of IF	Text	JC, JF, CC	At creation of request	All	RPWS	Electronic message	VMF K02.06	
	Threat Detection Start Time		Time threat is detected and	minutes	xxx.xx	At start of detection box	All	RPWS	Electronic message	VMF K02.07	

Figure 4-5. Example IDRL Data Requirements Sheet

5
MANAGE TEST EXECUTION

This chapter addresses the evaluation thread for CTM 5 Manage Test Execution. It focuses on the requirements to complete and implement a DMP with the end result of capturing test data. Section 5.1 provides a description of the steps, processes, and sub-processes that are part of the evaluation thread. Follow-on sections in the chapter provide the detailed instructions to guide the analyst in conducting the evaluation methods and processes.

5.1 Capability Test Methodology (CTM) and Processes for CTM 5

The fifth step in the CTM is to manage the execution of the test. This step covers final planning and preparation to include the development of an Event Management Plan (EMP), test personnel training, and the conduct of test spirals. These processes, shown in Figure 5-1, are the responsibility of an event manager; however, the analyst is involved in two sub-processes (CTM 5.1.2 and CTM 5.2.4). Highlighted in Figure 5-1, the two sub-processes will be the focus of discussion in this chapter.

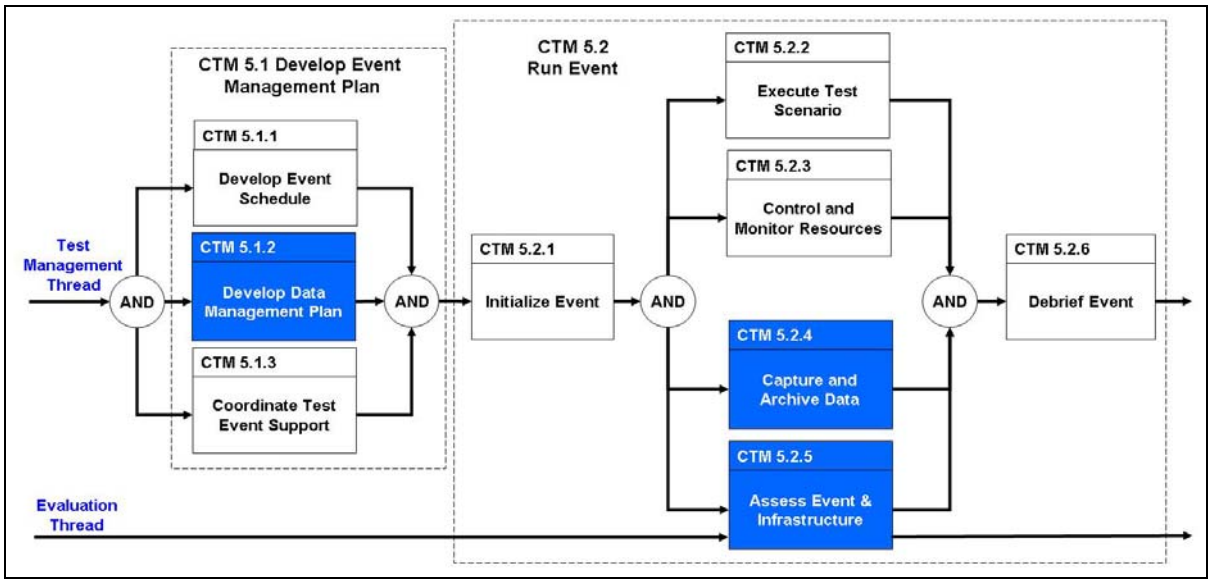

Figure 5-1. CTM 5 Manage Test Execution

The CEM components of CTM 5 Manage Test Execution are the JME Foundation Model (JFM), the logical design model (LDM), the physical design model (PDM), the PDM transformation, the JME interface and the actual JME. Figure 5-2 shows the components and the relationships of the LVC-DE branch of the CEM, which correspond to CTM 5.

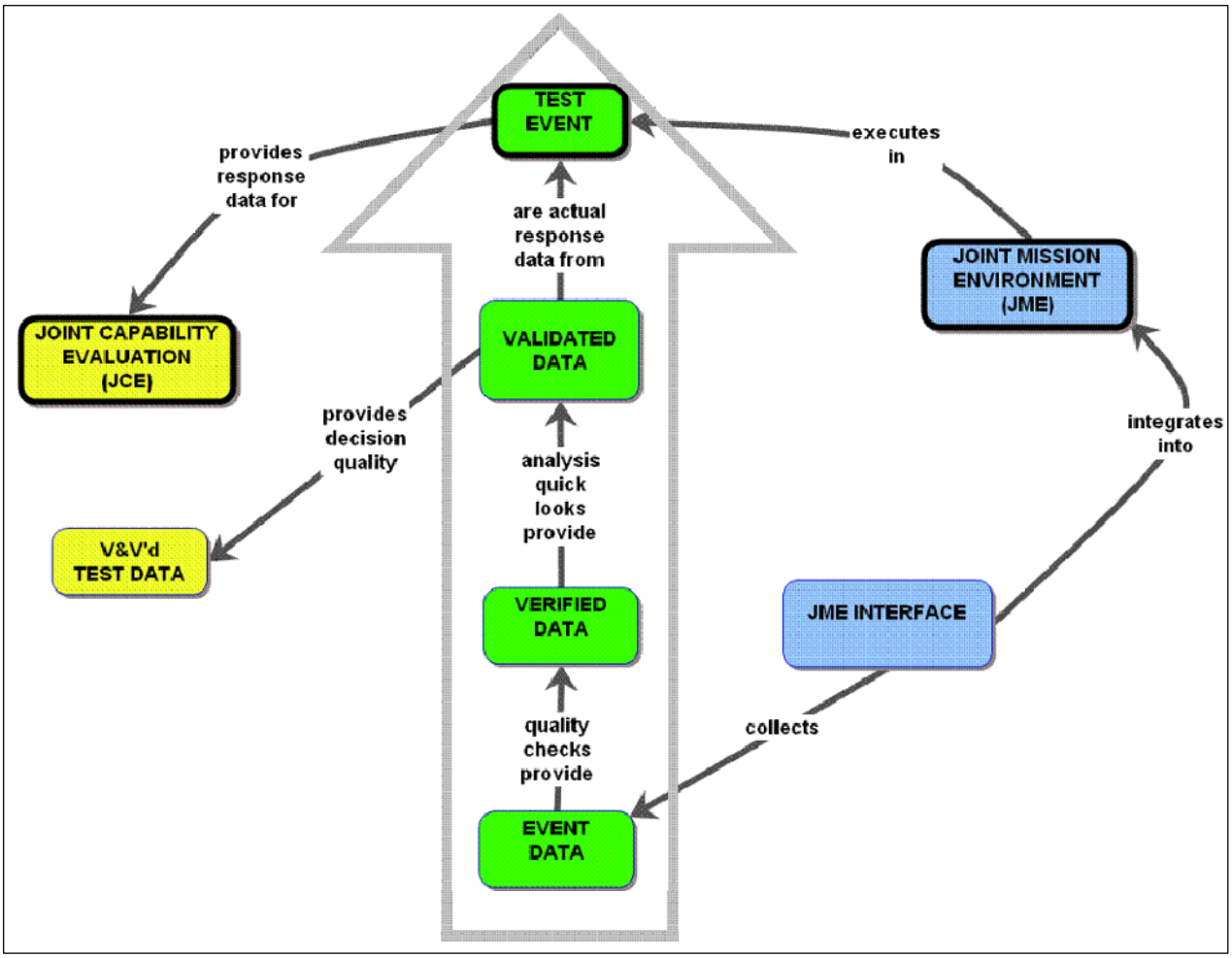

Figure 5-2. CEM, Run Event

CTM 5.1 ***Develop an Event Management Plan.*** An EMP is developed to ensure all participants understand the process. The EMP delineates test event leadership authorities and responsibilities, C2, issue resolution (both within individual sites and between distributed sites), and provides a common lexicon. Individual range/site business practices/aspects are considered when developing the EMP and standardized where practicable. The EMP needs to include the "who": Who defines a successful test and who is responsible for tracking progress across the distributed environment and making execution decisions during the test. Of primary concern to the analyst is the DMP.

CTM 5.1.2 ***Develop Data Management Plan.*** The DMP formally documents the intended course of action for collection, distribution, analysis, reporting, and archiving of data products during the test event. It should provide detailed procedures for collecting the raw test data, collating the data into a relational database for reduction and processing the data to a format compatible with analytic requirements, validating and analyzing the data, and providing data reports which are accessible to the analysts to support determination of a system's operational effectiveness and suitability. This process is depicted in Figure 5-3. The DMP is a separate document, but it aligns with the test plan and analysis plan in terms of

contribution to a successful test. The DMP is both a planning tool to ensure procedures are in place for data collection and a data management tool for tracking and assessing data collection during test execution. Execution of the DMP during integration events and the test event helps to ensure that collected data are sufficient to meet the analytical, operational, and technical requirements for the test event.

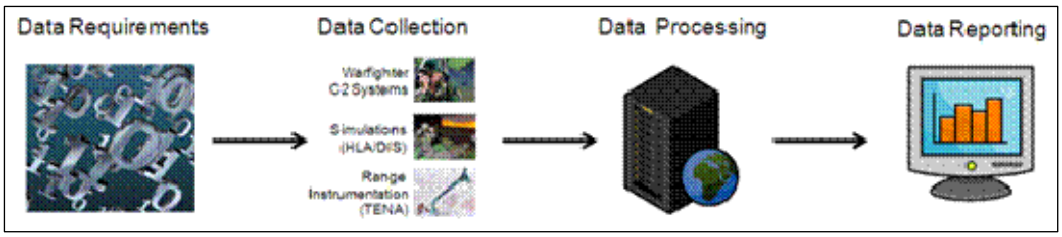

Figure 5-3. Data Management Process

CTM 5.2 *Run Event.* When the event planning and preparation are complete, the test manager will issue instructions to the test participants to run the event. Final test spirals or dry runs may occur as part of the event to ensure all systems and instrumentation are in place and operating normally. Dry runs will also help to ensure test participants understand their roles and responsibilities in the test event. The main component of this sub-process is the actual conduct of the test event that provides sufficient data that will support the analysis step of the CTM process.

CTM 5.2.4 *Capture and Archive Data.* From an analytical viewpoint, the goal of any test should be the accumulation of standardized data that are easily discernible by the analyst and applicable to the appropriate chosen analytical techniques in order to arrive at consistent conclusions regarding how the items under test performed. This requires executing the procedures addressed in the DMP in order to capture the test data in a single repository that can be archived for later analysis. Due to the vast amount of data transferred and collected during the conduct of a test, it is important to ensure the DMP is followed and data are verified. It is critical that the data are managed and properly handled. If anomalies are found in the data (incomplete or wrong data) it may be necessary to adjust the test design in the number of iterations or the scope of the test event. The right sample size, or number of tests, is dependent upon how much risk the customer is willing to accept. It is the responsibility of the test manager to explain the cost, risk, and benefits of different sample sizes to the customer.

CTM 5.2.5 *Assess Event and Infrastructure.* An event is conducted for the primary purpose of creating data that can be analyzed to form findings and recommendations about the SoS under test. From that perspective, the analyst must assess that the event provides relevant data and quantifiable results that will allow for the evaluation of the SoS performance, task performance, and mission effectiveness. This requires the analyst to select event output data for real-time analysis to verify and validate that the event is providing the right data to support a complete assessment as outlined in the DAP. Any deficiencies should be reported to the test manager to determine what corrective actions are required for event execution or infrastructure.

5.2 Instructions for CTM 5.1 Develop Event Management Plan

This section described the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 5.1.

(1) **Purpose**: The analyst must ensure the DMP and overarching EMP are sufficient to meet the requirements of the DAP.

(2) **Discussion**: The EMP must describe "how" the test event will be conducted and "who" does what to execute it. The analyst must ensure the EMP includes the major components of the analysis plan to include the DOE, data collection requirements, and a DMP. The DMP must address test information management issues that include:

- Control processes.
- Hardware and software involved in collecting, storing, archiving, validating, retrieving, processing, and analyzing test data.
- Development and maintenance of databases, catalogs, and libraries for data archival and retrieval.
- Determination of the requirements for the positive control of test data during and after the test event.
- Classified or special access information used or generated during the test may require additional handling and storage requirements that must also be considered during the planning phase.

(3) **Tools and Techniques**: The analyst supports the development of the EMP by developing a DMP. It is recommended a data manager be identified; then the analyst would provide support to the development of a DMP. If there is no data manager, then the analyst needs to draft a DMP. A sample DMP is provided in annex I to assist in this process.

(4) **Inputs**: Figure 5-4 identifies sources of suggested information for executing this section of the CTM. Described below are the required inputs; the remaining sources are optional.

Test Plan. A synthesis of operational, technical, management, and support functional areas of the test planning phase that are documented in an overall, coordinated test plan. Elements of the test plan include the data analysis plan, the data collection matrix, vignette, LVC-DE functional design, and test support plan. Administration and management (test organization, test control, and test readiness), test schedule, and cost estimate descriptions are further coordinated and incorporated into the test plan.

Data Analysis Plan (DAP). The DAP provides detailed procedures for the collection, reduction, collation, and analysis of data gathered to support determination of a system/SoS operational effectiveness and suitability. The DAP aligns with the test plan, contributing to a successful test, and is a planning tool to ensure procedures are in place for assessing data collection upon completion of test execution. The DAP is designed to provide the specifics for the analysis of operational effectiveness and

suitability of a system/SoS. The DAP should be completed before the test event begins to ensure the needs of various system/SoS customers will be met and that the resources are available to complete the data analysis. The DAP should include the purpose of the data analysis, data sources (including a description and any limitations), key variables to be used, and the data analysis methods. The capability manager should review the plan to ensure the proposed data analysis will answer relevant questions. Data analysis experts should review the plan to ensure the appropriate data and methods are used. The capability manager should approve the DAP.

Recommended Input Info/Sources	Products	
5.1 Develop Event Management Plan		
	❑	Event Management Plan
5.1.2 Develop Data Management Plan		
▪ Test Plan ▪ Draft Data Analysis Plan ▪ Test Trial Matrix ▪ Vignettes ▪ DoDAF Products (AV-2, TV-1, OV-1, 2, 4, 5, 6c, 7, SV-1, 4a, 4b, 6, 10c, 11	❑	Data Management Plan
	❑	Final Data Analysis Plan

Figure 5-4. CTM 5.1 Develop Event Management Plan Checklist

(5) **Actions**: The analyst provides support in the development of the EMP.

Gather required inputs. Provide the DAP and any other supporting documentation that identifies data elements, data collection requirements, test factors, and test trials.

Support the development of the Data Management Plan (DMP). Assist or lead the development of the DMP that addresses the collection, reduction, collation, and initial analysis of data issues.

Review the Event Management Plan (EMP). Assist in the development and review of the EMP. Ensure the EMP support the requirements of the DAP.

(6) **Outputs**: A complete and executable DMP and DAP is the required output that supports the evaluation thread within the CTM. Without a proper DMP and DAP, the collected data from the test event may not support the analysis step of the CTM as outlined in the DMP. See Annex I for a sample DMP. See Annex J for a sample DAP.

5.3 Instructions for CTM 5.2 Run Event

This section describes the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 5.2. This section is not intended to address every aspect of analysis in

the execution of an event, but only focuses on the analytical processes as documented in the CTM. It is expected that the analyst is knowledgeable in automated and manual data collection.

(1) **Purpose**: The analyst must ensure the capture and archiving of data during the execution of the test event. This includes a verification of completeness and accuracy that will support the DAP.

(2) **Discussion**: In preparation for the event, spirals or dry runs may be used as final verification of the test environment to include the test instrumentation and data collection systems. The analyst should ensure the data collection systems are properly working to provide complete and accurate data for post-test analysis. Any discrepancies must be immediately identified and brought to the attention of the test event manager for correction. Once the actual test event commences, the analyst must ensure all data are captured and archived as directed in the DMP. An initial assessment of the data should be conducted as early as possible to ensure data integrity, completeness, and reliability. This will provide the opportunity during test execution to correct and/or re-run test trials as needed to ensure adequate data is available for the analysis of the SoS.

(3) **Tools and Techniques**: The analyst employs the analysis and data management teams as needed to support the capture and archiving of data. Automated data collection systems are most desirable in a distributed environment. Analysts should be trained in the automated system to query the data and to conduct an initial check of data. One such tool which may be considered is the Digital Collection, Analysis, and Review System (DCARS), developed by the US Army Electronic Proving Ground (EPG).

(4) **Inputs**: Figure 5-5 identifies sources of recommended information for executing this section of the CTM. Described below are the required inputs; the remaining sources are optional.

Data Management Plan (DMP). The DMP provides detailed procedures for collecting raw test data, collating the data into a relational database for reduction and processing the data to a format compatible with analytic requirements, validating and analyzing the data, and providing data reports which are accessible to the analysts to support determination of a system's operational effectiveness and suitability.

Recommended Input Info/Sources	Products	
5.2 Run Event		
5.2.4 Capture and Archive Data		
▪ Data Management Plan ▪ Data Analysis Plan ▪ Test Plan	❑	Archived Data
5.2.5 Assess Event and Infrastructure		
▪ Data Management Plan ▪ Data Analysis Plan ▪ Test Plan ▪ Test Data	❑	Quicklook Evaluation

Figure 5-5. CTM 5.2 Run Event Checklist

(5) **Actions**: The analyst provides support in the execution of the test event.

Gather required documents. Provide the DMP and the DAP.

Assess data collection systems during spirals and dry runs. Assess the data collection systems and procedures for data completeness and accuracy. Report discrepancies to the test event manager. Determine if the discrepancies can be corrected or mitigated.

Capture and archive data. Support the data collection manager in capturing and archiving data. Conduct an initial assessment of the data for completeness and accuracy. Report any issues to the test event manager.

(6) **Products**:

Archived data. A complete set of archived data is the required output to support the analysis thread within the CTM. Without proper data, the analysis step may not be fully completed or provide supportable analytical results.

Quicklook evaluation. A quicklook evaluation of SoS performance, task performance, and mission effectiveness measures that will assess if the event is providing acceptable outputs to support the overall evaluation process.

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6
EVALUATE CAPABILITY

This chapter addresses the evaluation thread for CTM 6 Evaluate Capability. It focuses on the requirements to conduct an evaluation of the data resulting from a test event and to integrate that evaluation into an overall evaluation of a joint capability. Section 6.1 provides a description of the steps, processes, and sub-processes that are part of the evaluation thread. Follow-on sections in the chapter provide the detailed instructions to guide the analyst in conducting the evaluation methods and processes.

6.1 Capability Test Methodology (CTM) and Processes for CTM 6

The sixth step in the CTM is to evaluate the capability. The purpose of ***CTM 6 Evaluate Capability*** is to assess the test issues developed in the evaluation strategy at the joint SoS and Service system levels. The processes include collecting data; analyzing the data with respect to the test objectives; and evaluating system/SoS performance, task performance, and contributions to JMe. Although this is the last step documented in the CTM, it may be an iterative process of evaluation across multiple test events. An evaluation of a single event may be conducted that partially evaluates the capability. The valuation would provide feedback to CTM 1 and follow-on test events for further evaluation. Thus the evaluation is iterative and builds as the test campaign proceeds as outlined in the CTM 1 evaluation strategy. This chapter will discuss a single iteration of the evaluation process. Figure 6-1 depicts the components of the evaluate capability axis of the CEM.

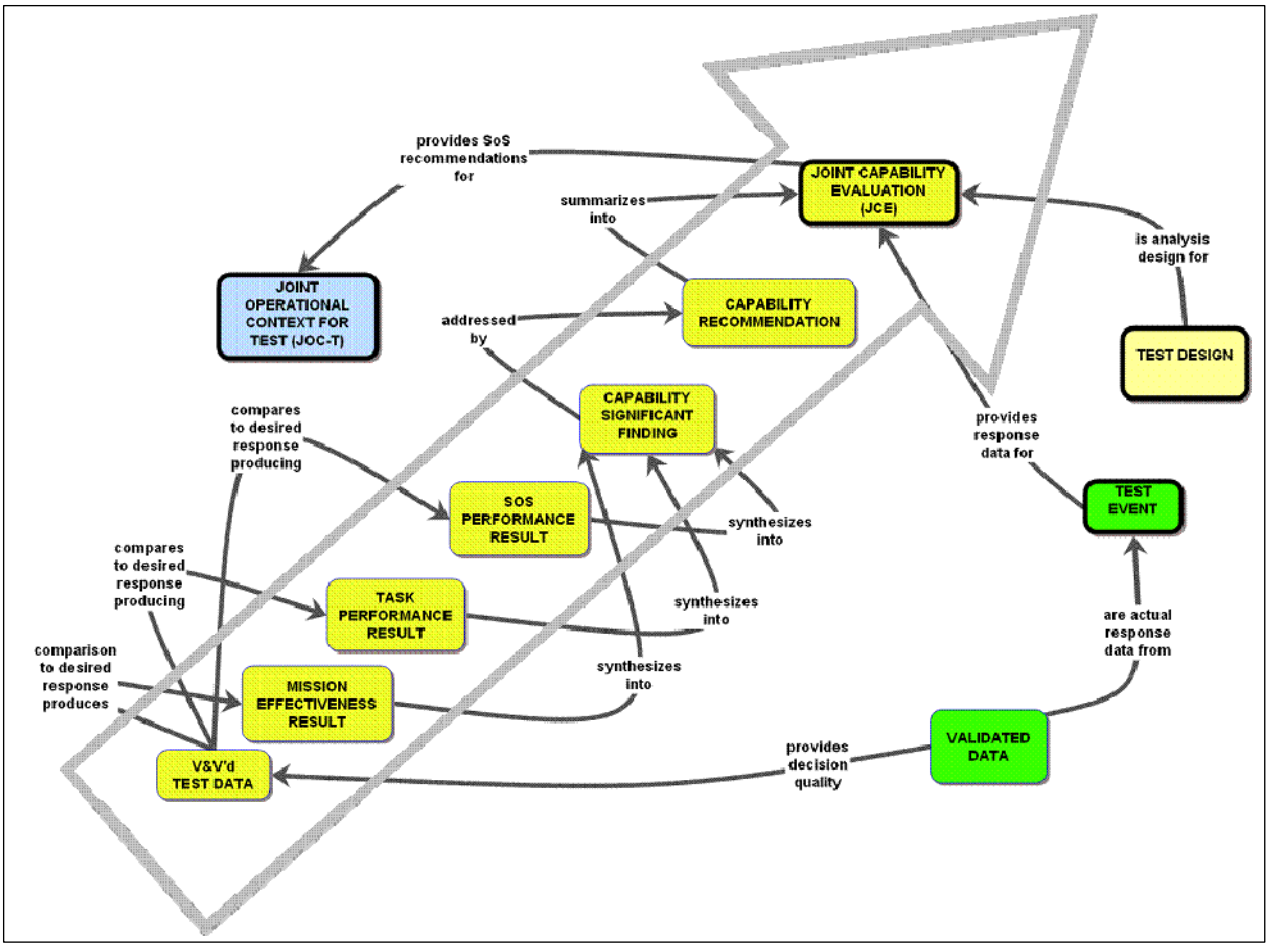

Figure 6-1. Evaluate Capability Axis of the CEM

This step focuses on the evaluation of data from one test event. This chapter focuses on three processes, shown in figure 6-2, ***CTM 6.1 Process Test Data, CTM 6.2 Analyze Data,*** and ***CTM 6.3 Evaluate SoS and Joint Mission Effectiveness (JMe)***.

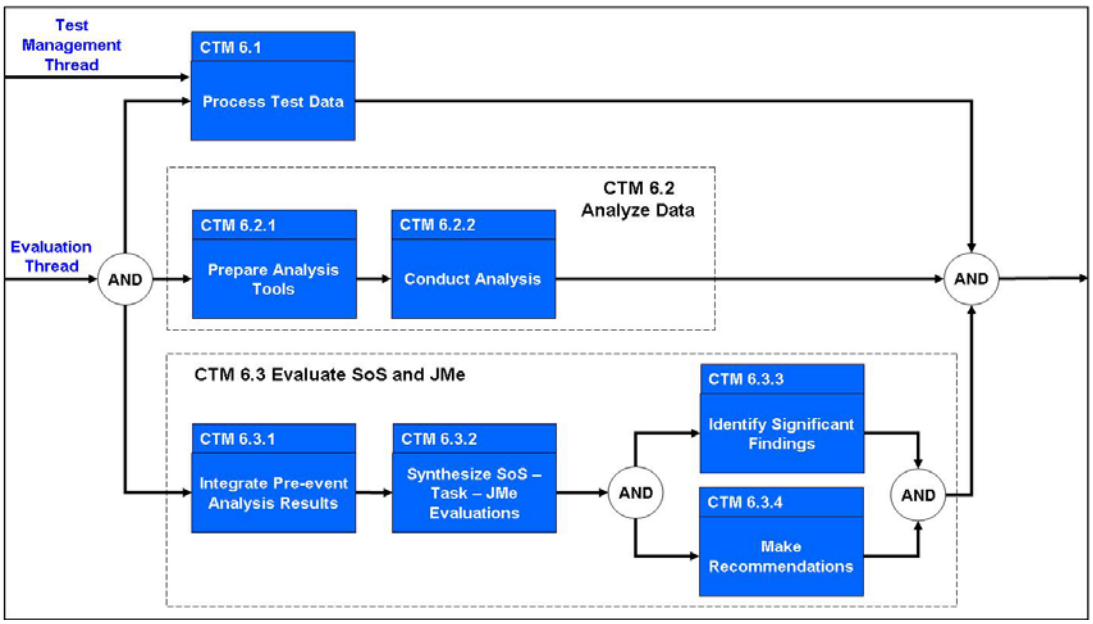

Figure 6-2. CTM 6 Evaluate Capability

The ideal output of this process is an objective evaluation of the SoS or SUT in terms of its contribution to delivering the intended capability, fulfilling a capability gap, and contributions to JMe. All the previous processes lead to this ultimate goal. It is this evaluation which is used by decision-makers to determine the future of those systems: to field them as is, to return them to PMs and developers for further work, or to cancel those programs in favor of others that are more promising. The PM should select systems that not only meet the KPP and KSA as outlined in JCIDS documents (CDD and CPD), but also demonstrate a beneficial and cost-effective impact on mission effectiveness in the SoS' operational context.

CTM 6.1 *Process Test Data.* Data processing and reduction includes all data handling from the source to input into the analysis activity. Data reduction is the process by which the analysis team manipulates the data set to prepare it for subsequent analyses. The data available to the team will likely have been collected from disparate sources, such as multiple models and simulations, as well as questionnaires, interviews, expert panels, and so forth. The data will be of varying quality and in different forms and may require further reduction and reconstruction to be useful for analysis. The goal of this process is to get the data into a consistent and usable form.

CTM 6.2 *Analyze Data.* Analyze Data turns the processed test data into information about what happened in the test and why it happened the way it did. Analysis can be thought of as a mechanical manipulation (hand or computer) and examination of actual data. Qualitative and quantitative data are analyzed to determine system/SoS attribute performance measures, system/SoS task performance measures, and JMe measures under various test trials. These measures are then analyzed across trials that vary a set of test factors to include different SoS configurations, SoS attributes, and conditions (both environmental and threat conditions). The results are assessed to measure the capabilities contribution to JMe and factor sensitivity to task performance and mission effectiveness.

CTM 6.2.1 *Prepare Analysis Tools*. This process should focus on the tools and techniques identified in the DAP. Tools refer to the actual means for accomplishing the analyses, and might include particular statistical software packages and databases, as well as other software with more specialized purposes, such as decision analysis software packages. Techniques deal with the methods that will be used in the analyses, such as traditional statistics, data mining, and decision analysis.

CTM 6.2.2 *Conduct Analysis*. This process is critical to the final evaluation. The analyst team examines and analyzes the data in order to draw the insights necessary to achieve the primary goal of the test data analysis – to evaluate the individual test measures responses and their relationships. In this process, the analyst will evaluate individual measure responses and their relationships. Figure 6-3 shows the two requirements of the analysis across the different levels of measures.

CTM 6.2.2.1 *Evaluate Individual Test Measure Responses*. This part of the evaluation is focused on evaluating each measure separately. Since there are three types of measures, each type has specific directions for evaluation.

CTM 6.2.2.1.1 *Analyze Mission Effectiveness*. This part of the evaluation is to analyze SoS contributions to JMe. This evaluation of Mission MOEs will focus on using quantitative and qualitative data to assess mission effectiveness outcomes across conditional threat and environmental factors and SoS configurations. These measures are used to assess changes in system behavior, capability, or operational environment tied to measuring the attainment of a mission end state, achievement of a mission objective, or creation of a mission effect. JMe is concerned with the big picture (performance at the mission level). Therefore factors that have greater impact at that mission level (conditions, SoS make-up) will be more important to the mission outcome. System or SoS level factors (attributes) may have lesser impacts at the mission level, but more of an impact at task performance. For example, the processing time for a call for fire may be the same regardless of whether the unit is conducting an attack or defending a forward operating base. At the mission level, the standards for Mission MOEs are likely to be wholly dependent upon the scenario conditions. For example, the standards for survivability are likely to be higher for a defense mission than they are for an attack. The analyst must understand the performance at the mission level in the context of the scenario conditions, and that the joint SoS may perform entirely differently for another scenario. This is why multiple tests across varied conditions are likely to be conducted.

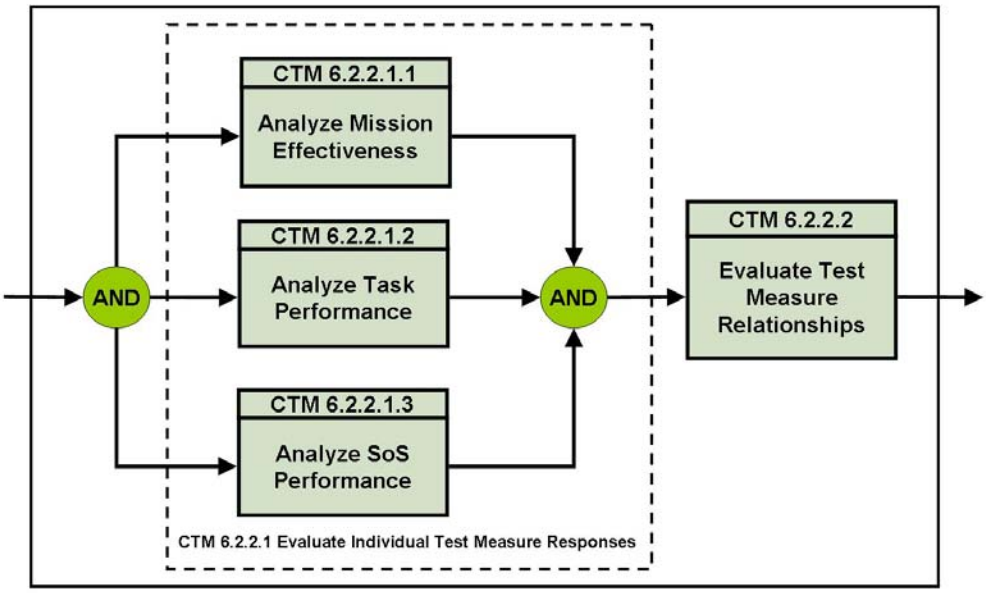

Figure 6-3. CTM 6.2.2 Conduct Analysis

CTM 6.2.2.1.2 *Analyze Task Performance*. This part of the evaluation analyzes SoS ability to perform tasks. Similar to the mission level, the analysis team will focus on using quantitative and qualitative data to assess task performance by the SoS across conditional threat and environmental factors and SoS configurations. These measures are used to assess changes in system behavior, capability, or operational environment tied to measuring the accomplishment of a joint or Service task. The idea of examining the performance of systems/SoS at the task level is similar conceptually to that for measuring mission effectiveness. The analyst will want to show the decision maker how different test factors, and combinations of factors, affected task performance and whether that performance met the required thresholds across the factor ranges of interest. One of the key factors will be the system involved, if more than one system is being compared. The analyst must have an understanding of the joint tasks and how the measures support them, because many of the Task MOPs will not evaluate the performance of the joint task as a whole, but will evaluate a particular aspect of it. The team must know which measures correspond to the same task and analyze those together. The analyst should look across tasks to gain insights about task performance as a whole. As before, there may be trade-offs to be made for performance at the task level, and these should be examined as well.

CTM 6.2.2.1.3 *Analyze System/SoS Performance*. This part of the evaluation is to analyze system or SoS performance. The analysis team will focus on using quantitative and qualitative data to assess KPPs, system/SoS MOEs, system/SoS measures of suitability (MOS), and system/SoS MOPs. The analysis should provide the statistical rigor and operational context to produce results that analysts and subject matter experts (SME) will use for evaluation of SUT(s) and SoS at the system/SoS level. Upon completion of this evaluation, the analysts and SMEs should have SoS performance information. The analyst should try to gain an understanding of how the

different factors tested affected system/SoS performance. Thus, the analyst should be able to show the decision maker how different experimental factors, and combinations of factors, affected system/SoS performance and whether that performance met the required thresholds across the factor ranges of interest. If systems are being compared, the analyst should be able to show the performance of one system relative to the others via standard hypothesis testing techniques. This is not as simple as it appears at first glance. A key challenge is the fact that there are likely to be numerous MOSAs against which the systems are being evaluated. Identifying systems that did not meet threshold values is fairly straightforward, but evaluating a system, whether individually or compared to other systems, based upon multiple measures is more challenging. The analyst cannot look at each measure in isolation, but must look across the measures to evaluate the system. The analyst should look at the correlation between the measures to identify trends or relationships between measures which may point to general strengths or weaknesses of the systems. Additionally, assuming that the systems met the threshold values set forth for the program, performance in different MOSAs often represent trade-offs that must be made. The analysis must be conducted in a way that will support decision making concerning these trade-offs. That often requires an understanding of the value of one MOSA versus another and may require decision analysis techniques.

CTM 6.2.2.2 *Evaluate Test Measure Relationships*. This part of the evaluation focuses on the interactions and correlations between multiple levels of measures to produce test results that measure a system/SoS contribution to system/SoS performance, task performance and JMe. This step is important because it identifies the cross-measure level relationships which drive the final evaluation; it goes beyond traditional hierarchical relationships and seeks to bring order to what would otherwise be a chaotic set of information. It purposely seeks to examine the cross-level relationships between measures rather than relationships at the same level. The analysis can involve multiple evaluate–analyze–evaluate iterations within a test. As a capability evaluation is developed, the evaluation results from selected areas of the test's parameter space may improve the overall mission and system-to-mission analysis models. Thus, an evaluation of one area may improve the analyst's understanding of another area, leading to iterative refinements. Between-test analysis iterations also occur as techniques/parameters are further refined throughout the acquisition life cycle as SUT/SoS fidelity increases. Combined, these analyses will help to produce the JMe information for the capability being tested. In this step, the analyst starts with the existing measure structure model to evaluate the relationships of the measure responses during the test. The team may discover that the test results contradict the original model. They must be careful to reexamine all of the relationships during this step; however, the original model provides the team with a starting point. Additionally, such information is essential for improving the exploratory analysis later if it is revisited for subsequent test events. The analysis will provide the underpinning of the team's evaluation of the JMe, and will thus directly impact the future of acquisition programs. For the systems/SoS under test, the analysis techniques used and the subsequent results may depend on the location of the systems/SoS in their acquisition lifecycle. The questions to be answered, which will drive the analysis, will likely vary accordingly. Some analyses should be common across

all tests. At the conclusion of this analysis, the team should understand how system-level performance (as evaluated by the MOSA) affected individual joint task performance (as evaluated by the Task MOP) and mission-level performance (as evaluated by the Mission MOE). Similarly, they should understand how task-level performance affected mission-level performance, and how performance at all three levels affected JMe as a whole. Thus, the analyst should be able to trace performance at each level through the other levels in the measure structure.

CTM 6.3 *Evaluate SoS and JMe.* This process requires the analysis team to consolidate all of the findings from the analysis of the data and draw key insights that will allow the team to report on overall JMe and make appropriate recommendations. The main steps of this process are shown in Figure 6-4. It should be noted that although the last two sub-processes are shown in parallel in the figure, there is a natural serial order (that follows the process numbering) that normally occurs. The steps can be, and often are, executed in parallel. With the synthesis of the evaluations, the team begins to identify significant findings and to make recommendations. It is expected the team will begin to formulate and refine recommendations as they begin to consolidate their findings. For instance, the team may look at the questions that they are required to answer in order to identify and group significant findings. Therefore, they may take a piecewise approach and address each question separately by grouping the findings and making recommendations relative the question. The team must ensure that they reexamine all of their findings and recommendations holistically before finalizing their evaluation.

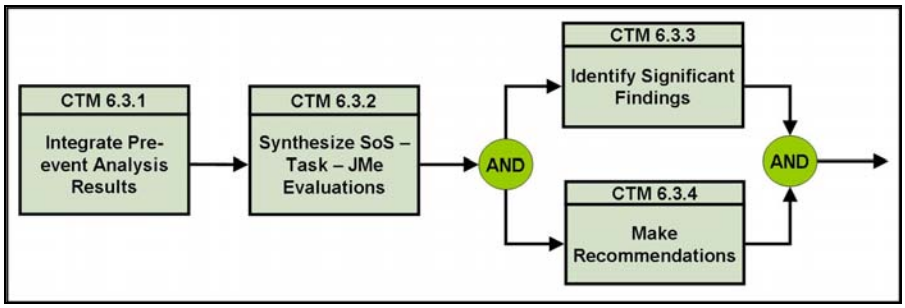

Figure 6-4. CTM 6.3 Evaluate SoS and JMe

CTM 6.3.1 *Integrate Pre-Event Analysis Findings.* The analysis team brings together the key results of any prior analysis (exploratory or from previous events) to fit the test results into a broader context and discuss agreement (or disagreement) between the pre-event work and the actual test events. In CTM 1, the overall JMe test factor space was developed and refined into a subset of that space, from which test trial sets were taken. An objective of each test event is to develop a summary performance evaluation and joint capabilities evaluation (JCE) based upon the data collected; however, only a limited subset of the possible conditions and scenarios will have actually been tested. If that limited subset was chosen via a good DOE in the exploratory analysis, then the team can say a lot about how inputs affect outputs. The test should be examined in context of the pre-event analysis. Integration of those preliminary results will provide insights into how the test results fit into the larger context of the test factor space and will help determine the feasibility of extrapolating the test results to the broader factor space for a joint capabilities evaluation. For instance, if the trends and results observed during the test event seem to exhibit the same trends and

relationships as that observed during pre-event analysis, the evaluators may conclude that the factor subset chosen for test was appropriate and representative of the most important factors. Additionally, the test results should be compared to any pre-event analysis results to validate (or not) assumptions that had been made. If major discrepancies exist between pre-event analysis results and the test results, a recommendation might be to revisit earlier analysis using the data obtained from the latest test event (as part of a model-test-model analytic framework).

CTM 6.3.2 *Synthesize SoS – Tasks – JMe Evaluations.* This process involves consolidation of the pre-event analysis results with all levels of measures to form a single picture of SoS performance in terms of delivering capability in support of mission accomplishment. The key results may be in different places or in different forms at this point, as expected due to the myriad of sources of raw data and tools used to support analysis. Additionally, not all of the results may help shed light on the questions to be answered. A simple collation of results, then, is not sufficient for a capability evaluation. The synthesis that should occur here is a matter of identifying, grouping, and relating key results. First, the analysis team will identify and select key results from the analysis that will directly support the questions to be answered and the recommendations to be made. They should then group those results into logical categories, possibly by the CCIs and the COIs. Finally, they will relate the results within and between the groupings and develop insights into what the analysis is conveying about the joint capability.

As part of this process, joint capability evaluation results are synthesized into a summary performance evaluation and the JCE can begin to be drafted. The JCE contains test findings and recommendations; it indicates impacts to test products and recommends possible transitions to the warfighter community. These findings are prioritized based on factors such as contribution to mission-desired effects, fulfillment of test goals, and considerations for risk, to produce a secondary listing of significant findings and critical test product issues to support SoS and system program acquisition decisions. The team can begin to develop the JCE by drafting the results and insights portions of the document. The JCE will then be developed further in the follow-on processes.

CTM 6.3.3 *Identify Significant Findings.* The analysis team captures and organizes the key results of the analysis to form foundations for the recommendations. From all of the analysis conducted thus far and the results synthesis, findings that have significant implications concerning the SUT or the joint capability are captured and organized. These findings will be the foundation for the recommendations made during the next process. They must be captured and put into context given the assumptions made throughout the test preparation and execution. The relationships between measures and their impact on mission effect or end state achievement should be reviewed and captured. Additionally, the final quantification of how the SoS or non-materiel changes impact the creation of a mission effect should be presented. In this process, the analysis team must tell the story that will lead directly to the recommendations. The analysis team should examine the evidence and present it in such a way as to suggest the recommendations even before they are made. All key evidence uncovered by the analysis team that has a significant impact on the conclusions must be presented. However, the team must still ensure that the information presented is arranged in

a way that leads to the recommendations. They must not expect the decision maker to sift through the results and findings to connect the dots.

CTM 6.3.4 *Make Recommendations.* A critical output of the entire CTM process is recommendations for decision-makers to field, continue development, or cancel those SoS involved in the test. The final recommendations should be based on the evidence and supported by the above analysis. As previously mentioned, if critical thinking was applied throughout the process and the results and findings are presented well, the results should be self-evident. Even so, players in the planning, programming, budgeting, and execution (PPBE) and acquisition systems rely on joint test results to support key decisions. At every milestone or control gate, a decision to move forward to the next phase of deployment is made. That decision can be one of three options: move forward unconditionally, return to early phases for more development work, or discontinue all investments and cancel the project. The recommendations made by the analysis should be very clear in this regard, supported with objective evidence and analysis involved in all the preceding steps. With the conclusion of this step, the joint capability evaluation should be in final draft and ready for review.

6.2 Instructions for CTM 6.1 Process Test Data

This section describes the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 6.1.

(1) **Purpose**: The analyst ensures data processing and reduction that will put the data into a usable form for analysis.

(2) **Discussion**: The identification of data collection requirements in the DAP and DMP should have affected how the data were collected during the actual test event. Nonetheless, the form of the data actually delivered to the analysis team may not be sufficient. The data may require further reduction and reconstruction to be useful for analysis. In any case, the reduced data will have to be organized into appropriate databases and statistical software packages to facilitate the follow-on analysis.

The data outputs from the models must be transformed into the particular data elements defined for each of the measures. If possible, the calculations required to convert a particular set of data elements into measures of interest may be conducted here as well. Additionally, the factor levels themselves may also have to be transformed for the analysis. The qualitative data may have to be transformed in some way as well, through binning, assigning them to particular qualitative levels, or converting them to numerical values (ordinal or nominal).

Processed data should be organized, reduced, prepared for analysis, and organized into tables capable of supporting analysis. Data should be able to be combined, selected, sorted, summarized, counted, and binned relative to any test condition. This will enable easy reconstruction of test conditions that generated any SUT or mission data for selective evaluation of any group of parameters. Groupings could be for an individual

SUT and mission data, or combinations of systems and mission data within a test event or across test events. Data can be grouped, sorted, and summarized by a multitude of detailed search parameters to determine under what test conditions the situation most frequently occurred. This approach provides maximum flexibility and allows for multiple levels of analysis, as required.

(3) **Tools and Techniques**: Data coding can be a useful data-reduction technique, and is particularly critical for questionnaire data in which the qualitative responses must be converted, or for transforming qualitative factor levels for numerically-based analyses. Additionally, data coding ensures consistency in identifying missing data so that they can be easily recognized later. Some statistical packages provide automated means to make data coding easier, particularly when the codes are assigned to a consistent set of qualitative levels. For some data types, such as interview data, the coding may need to be done by hand using analyst or expert judgment.

(4) **Inputs**: Figure 6-5 identifies sources of information that are desired for executing this section of the CTM. Described below are those required inputs. The remaining sources are optional.

Data Analysis Plan (DAP). The DAP should include the purpose of the data analysis, data sources (including a description and any limitations), key variables to be used, and the data analysis methods.

Data Management Plan (DMP). The DMP should contain the detailed procedures that were used in the test event for collecting raw test data and for collating the data into a relational database for reduction and processing the data to a format compatible with analytic requirements.

Recommended Input Info/Sources		Products	Example
6.1 Process Test Data			
▪ Data Management Plan ▪ Data Analysis Plan ▪ Test Plan	❑	a. Processed Test Data	
	❑	b. Reconstructed Mission Level Data	
	❑	c. Reconstructed Task Level Data	
	❑	d. Reconstructed System Level Data	

Figure 6-5. CTM 6.1 Process Test Data Checklist

(5) **Actions**: The analyst will work with data managers and data collection system personnel to process the test data into a usable format.

Review required inputs. Review the required inputs for data requirements and planned analysis tools and techniques that will be used to process the test data. Understand what data elements, data fields, metadata, test factors, and test trials are to be collected.

Reduce the test data. Assist or lead in the reduction of test data into data fields as required in the DAP and the IDRL. Standardize data measurements as needed. Transform qualitative data to quantitative. Convert to numerical values (ordinal or nominal).

Process the test data. Assist or lead in the processing of data organized into tables capable of supporting analysis.

Reconstruct data at measurement levels. Organize the data into different levels to measure mission effectiveness, task performance, and SoS attributes.

(6) **Products**: The output from this process is a set of processed data that will meet the analysis requirements at the mission level, task level, and SoS/SUT level.

6.3 Instructions for CTM 6.2 Analyze Data

This section describes the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 6.2. This section is not intended to address every aspect of analysis, but focuses on the evaluation thread as documented in the CTM. It is expected that the analyst is knowledgeable in analytical tools and techniques.

(1) **Purpose**: The analyst examines processed data to assess SoS contributions to JMe as well as task performance, and SoS/SUT performance. The goal is to assess an SoS ability to either fill a capability gap at the joint mission level or enhance an existing joint capability and to provide recommendations on materiel and non-materiel attributes of that capability.

(2) **Discussion**: The analyze data process involves examining the processed test data (test data combined from all sources into a condensed and readable format), choosing the techniques to analyze, and conducting the analysis of the data. The joint perspective requires examination, analysis, and later evaluation at the SoS and JMe level while the system focus is on task performance and SUT attributes. This process not only analyzes the individual system performance but also the SUT/SoS enhanced performance to accomplish the joint level tasks contributing to the effectiveness of the joint mission. This process involves using tools such as statistical software, database software, and other related tools required to reduce and analyze the data. More importantly, it requires the analysts to draw general conclusions on SoS performance, task performance, and JMe. The relationships between the different levels of measures should be documented in the DAP. The analyze data process can be sub-divided into two components: (1) prepare analysis tools and (2) conduct analysis (see Figure 6-2). The analytical tools to be used should have already been identified in the DAP. Some preparation may be necessary before conducting the analysis.

(3) **Tools and Techniques**: The tools and techniques should have already been identified as part of the DAP. The analysis team may need to reassess the analytical tools to ensure they have the tools for the task, instead of forcing the analysis to fit the capabilities of the

planned tools. It is very probable at this point in the process, there may not be an opportunity to change the tool selection. Therefore, this process should focus on the techniques that need to be further developed based on the available tools. Possible techniques for evaluating individual test measure responses may include analysis of correlation, regression analyses between levels, and other qualitative techniques. Techniques for evaluating measure relationships at different levels may include the Matrix of Failure Mode Effects Analysis (MFMEA). MFMEA follows a systematic inductive approach to map the relationships between basic failures at a low level and their impacts at the higher levels. Another technique might include the use of systems dynamics simulations, which provide insights into second- and third-order effects by modeling the system structure and feedback loops. In this technique, the analyst would develop the SoS structure in the model and populate it with data from the test. Further discussion of analysis tools and techniques may be found in Annex G (Analysis Techniques).

(4) **Inputs**: Figure 6-6 identifies recommended sources of information for executing this section of the CTM. Described below are the required inputs; the remaining sources are optional.

Data Analysis Plan (DAP). The DAP should indicate what analysis tools and techniques were planned and indicate how each measure was to be evaluated. Most of this information should be available in the DAP evaluation views.

Processed test data. Processed data is in a consistent and usable form for analysis. This includes data that is reconstructed or sub-divided to assess mission effectiveness, task performance, and SoS/SUT performance.

Recommended Input Info/Sources		Products	Example
6.2 Analyze Data			
	❑	Capabilities Analysis Information	
6.2.1 Prepare Analysis Tools			
▪ Data Analysis Plan	❑	a. Analysis Tools	
	❑	b. Analysis Techniques	
6.2.2 Conduct Analysis			
▪ Processed Test Data	❑	a. Joint Mission Effectiveness Evaluation	
	❑	b. Task Performance Evaluation	
	❑	c. SUT/SoS Performance Evaluation	

Figure 6-6. CTM 6.2 Analyze Data Checklist

(5) **Actions**: The analyst shall lead the process to analyze data from the test event.

Review the DAP. Review the DAP to determine what analysis tools and techniques were planned and how each measure was to be evaluated.

Assess required changes to tool and technique selection. Assess the availability of planned tools and the ability to perform the desired analysis techniques. Modify as needed.

Evaluate individual test measure responses. Evaluate individual measure responses for each of the three levels of measures, to include a determination of effects of the factors on those measures.

Evaluate test measure relationships. Examine the relationships between the measures responses both within a particular measure level and between levels.

(6) **Products**: The output of this process is an objective evaluation of the SoS or SUT in terms of its contribution to delivering the intended capability and contributions to JMe. All the previous processes lead to this ultimate goal. It is this evaluation which is used by decision-makers to determine the future of those systems: to field them as is, to return them to PMs and developers for further work, or to cancel those programs in favor of others that are more promising. The PM should select systems that not only meet the KPP and KSA as outlined in JCIDS documents (CDD and CPD), but also demonstrate a beneficial and cost-effective impact on mission effectiveness in the SoS' operational context. This can be a very politically-charged evolution, so the analyst is cautioned to exercise objectivity and be aware of ethical implications. The outputs will consist of an evaluation of measures at each of the three levels of measurement (mission, task, and SoS) as well as an evaluation of the test measures relationships. The analyst will

determine the format that documents the results; as this may be based on the selection of utilized tools and techniques.

6.4 Instructions for CTM 6.3 Evaluate SoS and JMe

This section describes the methods and processes for the analyst to prepare and execute the evaluation thread in CTM 6.3. This section is not intended to address every aspect of analysis, but only focuses on the evaluation thread as documented in the CTM. It is expected that the analyst is knowledgeable with analytical tools and techniques.

(1) **Purpose**: The analyst must use the analyzed test results and pre-event analysis to evaluate the SUT/SoS and JMe. The goal is to provide findings and recommendations on materiel and non-materiel attributes of that capability that will aid the PM in making acquisition decisions.

(2) **Discussion**: Once the test data have been analyzed, the analysis team uses test results to evaluate SUT/SoS performance, task performance, and contribution to JMe. The analysis team brings together the key results of any pre-event (exploratory or prior test event) analysis to provide insights that fit the test results into a broader context and discuss agreement (or disagreement) between the pre-event work and the actual test events. Pre-event analysis and findings are synthesized at all three levels of measures to form a single picture of SoS performance in terms of delivering capability in support of mission accomplishment. The analysis team must capture and organize key results of the analysis to form foundations for the recommendations. The final output is to provide recommendations for decision-makers to field, continue development, or cancel those SoS involved in the test. The analysis and recommendations will also support further testing of the capability as planned in the evaluation strategy.

(3) **Tools and Techniques**: Using statistical and other analytical results regarding the system or SUT across test trials and types of measures, conclusions are reached as to the system/SoS contributions to overall mission performance in the JME. Due to the complex nature of SoS interactions while testing in a joint environment parameter space, analysts need to explicitly state conclusions in terms of assumptions that were made throughout the CTM process. The assumptions should be related to test factor variations and controls during the test. When rigorous statistical significance is not found concerning test hypotheses, analysis can provide trend-line indications of system/SoS contributions to mission effectiveness, which can be further explored in follow-on test events. Evaluation takes the results of the analysis and applies additional reasoning (mental manipulation) to arrive at conclusions and recommendations. Some analytical tools and techniques available to the analyst are listed in Figure 6-7 and described in Annex G (Analysis Techniques).

- Alternative identification, evaluation, and comparison techniques
- Statistical analysis tools
- Database tools
- Statistical techniques
  - Box plots
  - Hypothesis testing
  - Confidence intervals
  - Regression
  - ANOVA
  - Correlation and cross-correlation matrices
  - Classification and regression trees
  - Contour plots
  - Response-surface methods
  - Advanced response-surface methodology
  - Nonparametric statistics
- Qualitative measure relationship techniques
- Matrix Failure Modes and Effects Analysis (MFMEA)
- Decision analysis techniques, such as multi-attribute decision making (MADM)

Figure 6-7. Potential Analytical Tools and Techniques

(4) **Inputs**: Figure 6-8 identifies sources of recommended information for executing this section of the CTM. Described below are the required inputs; the remaining sources are optional.

Data Analysis Plan (DAP). The DAP should indicate what analysis tools and techniques were planned and indicate how each measure was to be evaluated. Most of this information should be available in the DAP evaluation views.

Pre-event analysis results. Key results of any prior analysis (exploratory or from previous events) that may provide a broader context of analysis with the test event results and that may provide higher level insights on capability performance and JMe.

Processed test data. Processed data is in a consistent and usable form for analysis. This includes data that is reconstructed or sub-divided to assess mission effectiveness, task performance, and SoS/SUT performance.

Recommended Input Info/Sources		Products	Example
6.3 Evaluate SoS and JMe			
▪ Data Analysis Plan	❑	Joint Capabilities Evaluation (JCE)	
6.3.1 Integrate Pre-Event Analysis Results			
▪ Pre-Event Analysis Results ▪ Processed Test Data	❑	a. Integrated Analysis Results	
6.3.2 Synthesize SoS – Tasks – JMe Evaluations			
▪ Integrated Analysis Results	❑	a. Synthesized JMe Evaluation	
	❑	b. Synthesized Task Performance Evaluation	
	❑	c. Synthesized SUT/SoS Performance Evaluation	
6.3.3 Identify Significant Findings			
▪ Synthesized JMe Evaluation ▪ Synthesized Task Performance Evaluation ▪ Synthesized SUT/SoS Performance Evaluation	❑	a. CCI Significant Findings	
	❑	b. COI Significant Findings	
6.3.4 Make Recommendations			
▪ CCI Significant Findings ▪ COI Significant Findings	❑	a. CCI Recommendations	
	❑	b. COI Recommendations	

Figure 6-8. CTM 6.3 Evaluate SoS and JMe Checklist

(5) **Actions**: The analyst will lead the process to evaluate the SoS and JMe.

Review the DAP. Review the DAP to determine which analysis tools and techniques were planned and how each measure was to be evaluated.

Integrate pre-event analysis. Select and integrate pre-event analysis (exploratory or earlier events) that may support or refute the analysis of test event data.

Identify significant findings. Capture and organize key results of the analysis process in terms of CCI and COI to form foundations for the recommendations.

Make recommendations. Develop recommendations for decision-makers in terms of CCI and COI, to field, continue development, or cancel those SoS involved in the test.

Develop JCE report. Develop a JCE report (JCER) that captures the findings and recommendations for the CCI and COI.

(6) **Products**: An integrated and synthesized analysis of the test event results with pre-event results are internal products that provide an analytical thread to the development of the findings and recommendations. The end product is the development of a JCER that will provide results to the decision-maker for acquisition decisions. The JCER will include an audit trail of deviations from the planned testing event and their impact on the evaluation, some of which may be captured in the test incident and corrective action reports. It will also include details such as test conditions and test results, detailed displays of data from the tests, and testers' observations. The findings, conclusions, and recommendations for SoS acquisition will be incorporated into the JCER. These recommendations should be prioritized based on factors such as feasibility, timeliness, and warfighter needs so that they can be readily implemented. Any assumptions that were made for this test or factors that could not be adequately analyzed should be highlighted so the readers will understand any limitations with the recommendations. A template for the JCER is found in Annex K (Sample Joint Capability Evaluation Report).

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