Test and Training ENabling Architecture (TENA)

TENA BASELINE PROJECT REPORT

Volume VI

TENA Application Concepts

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Abstract

An *application concept* is the name given to a group of methods or procedures that show how to use architecture components to solve primary customer needs.

TENA defines three application concepts:

- The *Logical Range Application Concept* shows how the TENA Object Model structure and the Logical Range Business Process Model work together to respond to the increased demand for multiple-site exercises and/or exercises which cross T&E/training or live/virtual/constructive boundaries.

- The *Systematic Reuse Application Concept* shows how the Product Line Approach (PLA) and object-oriented Technical Reference Architecture reduce software development and maintenance costs, support utilization of common instrumentation at multiple facilities, and respond to the increased demand for consistency of information between facilities.

- The *Continuous Insight Application Concept* shows how the customer focused object structure, together with the Logical Range Application Concept, allows for consistency of information across phases of the acquisition process and the capturing of critical data to support informed customer and management decisions about resource needs, capabilities, and investments.

The Logical Range Application Concept supports high-level requirements for: integrated test and training, re-engineered acquisition process, model and simulation reuse, and exercise complexity and realism. The Logical Range Application Concept description offered demonstrates how the TENA Object Model and Logical Range Business Process Model work together to meet customer requirements.

The opinions, ideas and recommendations presented in the TENA Baseline Project Report are the views of the TENA Project Team and do not necessarily represent those of the Sponsor.

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Purpose

This document demonstrates how multiple components of the TENA Architecture work together to support defined TENA Application Concepts.

These concepts are fundamental to successful implementation of TENA. In this Baseline Report we focus on the Logical Range Application Concept.

Readership

This volume is intended for range management, operation directors and others in a range-management oversight or DoD and Service decision-making role. It will also be useful for software designers who wish to see how components of the architecture work together to support TENA Application Concepts.

Relationship to Other Volumes

Other technical information is found in different volumes of the TENA Baseline Project Report. Of most importance to this Application Concept document are the Product-Line Approach [TENA, 1] (Volume II), the Technical Reference Architecture [TENA, 2] (Volume IV), and the Logical Range Business Process Model (LRBPM)[TENA, 3] (Volume V). The PLA is fundamental and essential to engendering the cost savings required of DoD ranges in the future, but also to breaking the paradigms of the present. The LRBPM presents a methodology for conducting test or training exercises on a TENA compliant range. A Glossary of Terms and Definitions is contained in Volume IX. Other supporting project information and documentation is presented in Volume X. Readers of this Application Concepts document are encouraged to seek additional detailed information by consulting the appropriate volume.

PROJECT NEED

TENA is part of a coordinated response by the Central Test and Evaluation Investment Program (CTEIP) office to several current and emerging challenges in the test and training range and resource community. These challenges include:

- Reducing software development and maintenance cost,
- Utilizing common instrumentation at multiple facilities,
- Responding to the increased demand for multiple-site exercises and/or exercises which cross T&E/training or live/virtual/constructive boundaries,
- Responding to the increased demand for consistency of information between facilities and across phases of the acquisition process, and
- Capturing critical data to support informed customer and management decisions about resource needs, capabilities, and investments.

PROJECT PURPOSE

The purpose of the TENA project is to respond to these challenges through the establishment of an architecture that efficiently and effectively fosters the sharing, reuse, and interoperability between cooperating Department of Defense (DoD) test ranges and facilities, training ranges, laboratories, and other modeling and simulation activities. The expected synergism will permit efficient and effective testing of new and enhanced weapons systems and will vastly improve the scope and fidelity of worldwide joint/combined training.

PROJECT HISTORY

The Test and Training ENabling Architecture (TENA) project concept was formulated in FY95 by a multi-Service working group. This concept was endorsed by the Test and Evaluation Reliance Investment Board (TERIB), the Board of Operating Directors (BoOD), and the Test and Evaluation Resource Council (TERC).

The Navy is the CTEIP Resource Manager for this project, and has established a Joint Project Office (JPO) for the management of project activities at the Naval Undersea Warfare Center (NUWC) Division, Newport, RI.

Shortly after assembly of the Joint Service Team, several critical observations were made:

- The key to interoperability is not connectivity alone, but rather understanding communications content. This is best promoted by defining an open, object-oriented software architecture that could be used by both legacy and newly built systems.

- The process used to plan, schedule, and otherwise coordinate a multiple-facility, multiple-service exercise must be integral to the development of the architecture, or the capabilities it offers might never be fully utilized.
- The architecture must be conducive to refinement over time and coexists with facility-unique applications. This requires a disciplined architecture development/refinement process. The team adapted the Defense Information Systems Agency (DISA) domain-engineering approach to help develop the architecture and recommends the Product-Line Approach for implementation and life-cycle maintenance.
- Significant investments are being made in other closely related areas such as, Defense Modeling and Simulation Office (DMSO), High Level Architecture (HLA), and the Joint Simulation System (JSIMS) program. TENA must leverage as many of these efforts as practical.
- The TENA concept is radically new to our community. Planning for transition is key to its ultimate acceptance.

STATUS

The project team tested its architecture development process in FY96 producing a "Pilot Architecture." This work was reviewed in several public forums. These reviews were highly supportive of TENA's effort. Two consistent suggestions were that TENA should focus first "on breadth, not depth", and that there should be more emphasis on "problem-space vs. solution-space". These considerations and additional engineering effort has resulted in this refined "Baseline Architecture."

The TENA Baseline contains sufficient detail to continue further analysis and risk reduction efforts and is a good vehicle for discussion, experimentation, and refinement. It is not yet appropriate to use these documents as the blueprint for a major system development. After community feedback, results from risk-reduction prototypes, experiments, and other ongoing efforts are synthesized, the cognizant TENA Baseline documents will be updated as "TENA Rev 0." TENA Rev. 0 will be the appropriate source of design information for a TENA-compliant system implementation.

WHAT IS AN APPLICATION CONCEPT

An *Application Concept* is the name given to a group of methods or procedures that show how to use architecture components to solve primary customer needs. TENA is constructed to meet several primary needs that are restated below**:**

- Reducing software development and maintenance cost,
- Utilizing common instrumentation at multiple facilities,
- Responding to the increased demand for multiple-site exercises and/or exercises which

cross T&E/training or live/virtual/constructive boundaries,

- Responding to the increased demand for consistency of information between facilities and across phases of the acquisition process, and

- Capturing critical data to support informed customer and management decisions about resource needs, capabilities, and investments.

Descriptions of each architectural component, such as the Technical Reference Architecture, Logical Range Business Process Model, or Product Line Approach, although they may include examples, are not intended to provide exposition of how several architecture components work together to support primary needs. This document provides a description of that interrelationship.

Application concepts occur in familiar environments like office computer word-processing and spreadsheet software. It is possible to gain a good understanding of the features of a word processor and a spreadsheet program as individual software tools. Most office software vendors support an additional application concept of "seamless data transfer" between programs, i.e. cutting and pasting spreadsheets into a word processor. This concept, supported by both the computer operating system and application programs, gives the user far more power than any individual application alone. The additional capabilities of the application concept are described at the operating system or application package level, not with every individual application.

TENA APPLICATION CONCEPTS

TENA defines three application concepts:

- The *Logical Range Application Concept* shows how the Object Model structure and the Logical Range Business Process Model work together to respond to the increased demand for multiple-site exercises and/or exercises which cross T&E/training or live/virtual/constructive boundaries.

- The *Systematic Reuse Application Concept* shows how the Product Line Approach and object-oriented Technical Reference Architecture reduce software development and maintenance costs, support utilization of common instrumentation at multiple facilities, and respond to the increased demand for consistency of information between facilities.

- The *Continuous Insight Application Concept* shows how the customer focused object structure, together with the Logical Range Application Concept, allows for consistency of information across phases of the acquisition process and capturing critical data to support informed customer and management decisions about resource needs, capabilities, and investments. [Kaminski, 1995]

Together the TENA Application Concepts cover all TENA primary needs.

This Baseline TENA Application Concepts volume explains the requirements for the Logical Range and describes the Logical Range Application Concept. Expository information on other application concepts, including an explanation of how the Continuous Insight concept supports the Simulation, Test & Evaluation Process (STEP) [STEP, 1996] will be added to subsequent releases of Volume VI.

The Logical Range is one application concept for the TENA architecture. It responds to several project needs but primarily addresses integrated test and training. TENA application concepts support several higher-level requirements. These requirements are resident in the three pillars: *reduction, restructuring, and revitalization*, the basis for our long-range strategy. [Sanders, 1997]

TENA is responding to the long-range strategy with an architecture, business process and a method for deploying both—the Product Line Approach. The application concept of the Logical Range is used to demonstrate how the TENA Object Model and Business Process function to support requirements for:

- Integrated test and training,
- Re-engineered acquisition process,
- Model and simulation reuse, and
- Exercise complexity and realism.

These general statements regarding the evolving strategy for test and training can be expanded.

INTEGRATED TEST AND TRAINING

Testers and trainers often leverage each other's facilities, but the processes are not based in any foundation architecture and consequently limited in the realizable level of integration. "Elimination of stovepiping and higher levels of integration can result in more productive and efficient utilization of range resources with no loss of effectiveness to either." [Sanders, 1997] While some integration of testing and training environments already occurs, substantial integration will require changes to range operations, infrastructure, operations and investment funding, and organizational structures. This convergence of perspectives contributes to the growing benefits of test and training integration. TENA products such as the PLA, Technical Reference Architecture and the Logical Range will provide the medium and technology to help realize this integration.

RE-ENGINEERED ACQUISITION PROCESS

The process whereby DoD acquires new weapons systems is being challenged in an unprecedented manner to become more effective and efficient. The changing world scene coupled with advances in and availability of sophisticated technologies has resulted in a reappraisal of the acquisition process. [DOD 5000.2R]

According to this reappraisal, DoD's traditional "test-fix-test" acquisition process is inherently costly and unable to quickly leverage innovative technology. "We will need a responsive research, development, and acquisition process to incorporate new technologies." [*Joint Vision 2010*] The DoD acquisition community recognizes these challenges and is in the process of re-engineering the acquisition process for major

DoD weapons systems. To perform rapid simulation based prototyping for concept and design validation, a "model-test-model" . . . build process is being adopted [TEMS, 1997] [M&SMP, 1996]. The "model-test-model" process eliminates much of the time and cost of physical prototyping associated with the traditional "test-fix-test" acquisition process.

Test & Evaluation engineering processes are well suited to the model-test-model build process [STEP, 1997] which links virtual, real, and constructive resources throughout acquisition phases. The Logical Range Application Concept links the virtual, real, and constructive resources. It supports the Continuous Insight Application Concept that is a method for implementing STEP across the test and training domains.

MODEL AND SIMULATION REUSE

The Defense Advanced Research Projects Agency (DARPA) estimates that typically 75 percent of the cost of developing a new simulation system goes into building the simulation infrastructure, while only 25 percent is used to develop components specific to the purpose of the simulation. Duplication of effort has mitigated any of the potential cost effectiveness promised by M&S.

A synthetic battlespace using a TENA Logical Range is envisioned as the technical and efficient response to this shortfall and, in the future, testers/trainers will rely on a combination of physical and synthetic resources. The key to any major weapon system acquisition has always been testing and evaluation in the correct operational environment. Similarly, the training community advocates "train as you fight, fight as you train" which can only be economically realized through application of M&S. The Logical Range, modeled on the functionality of current instrumented ranges, will allow any user to identify requirements and satisfy them through the dynamic networking of virtual, real, and constructive assets.

EXERCISE COMPLEXITY AND REALISM

There is strong need in DoD to provide an environment or battlespace capable of meeting complex scenario requirements and achieving more realism. DoD is burdened with mission oriented, stove-piped systems and requirements at a time when a potential solution is available to seamlessly and synergistically integrate across domains and systems. Most efforts, to date, have not been supported by a strong architectural foundation that promotes rapid deployment of exercise scenarios.

New weapons are employing technologies that cannot be tested or exercised using current test and training scenarios that are limited by many factors including model capabilities, data rates, data acquisition schemes, command and control issues and environmental concerns. TENA can provide support for removing some of these limitations.

The Logical Range is a temporary association of a set of test and/or training resources

for the purpose of supporting a test or training exercise. A resource can be real or virtual or constructive and can represent measurement systems, environments, personnel, equipment or any grouping required to meet exercise requirements. A Logical Range is very much like a typical test or training Open Air Range (OAR), except that it may use resources from multiple physical ranges and/or other cooperating test and training resources. The Logical Range is a dynamic entity that can be re-composed at any time. It is analogous to a physical range without geographic boundaries, which is created to support the needs of a particular test or exercise for a specific customer. The Logical Range is intended to make interoperability between ranges and between ranges and non-OAR facilities, a routine capability.

The Logical Range provides the customer with a rapidly configurable environment within which to thoroughly test and meet the test and training needs of new and expanding technologies which can only be served in a multi-site, multi-Service mission space environment. It also represents a viable means to conduct multiple levels of training, either separately or in conjunction with acquisition-related test programs.

Conceptual View

The traditional test and training process uses a physical range as the mission space within which exercises occur. Often, the need to link ranges and facilities, in support of large terrain objectives, results in ad-hoc connections as depicted in Figure 1. These arrangements typically require custom interfaces which are costly, time consuming, and generally inadequate.

Figure 1. Current Interoperability Approach

TENA provides a formal definition of models, processes, and standards that will enable this distributed environment we call the Logical Range. The Logical Range extends the physical limits by seamlessly connecting facilities without the need for custom interfaces to convert information. Figures 2 and 3 show different conceptual views of the Logical Range. In both figures the Logical Range exercise is supported through dynamic composition of assets assembled from physical ranges, hardware-in-the-loop (HITL) facilities, laboratories, or other sites where potential mission space entities exist. The assembled combination of components is uniquely defined to perform a specific test or training exercise. Each site is private, and locally managed and supported in

accordance with the principles of the sponsoring organization.

Figure 2. Conceptual View 1 of the Logical Range

The user shown in figure 2 could be physically located at any of the facilities or connected remotely via a TENA-compliant interface. A Logical Range Support Tool will be available to users of TENA-compliant systems to support test and training exercise definition, scheduling, planning, execution monitoring and control, and closeout functions.

Figure 3, shows an expanded view of a notional mission space. It illustrates how assets from a variety of ranges or facilities come together to create a Logical Range environment.

This section will provide a brief description of how two TENA components are used to create a Logical Range. The Logical Range Business Process Model and the TENA Object Model contribute to the Logical Range by providing a definition of standard processes and object classes respectively. Brief descriptions of both TENA Object Model and LRBPM views are provided as background. Detailed explanations are found in Volume IV and V of the TENA Baseline Report. A walk-through of an example Logical Range exercise is provided to illustrate the concept. In facilitating distributed test/training exercises, the Logical Range provides a variety of benefits that will be identified at the end of the description of each phase.

Most of the interaction among Logical Range objects is embodied in tools such as a browser and enabling add-on applications (e.g. sort, display, schedule, etc.) that will support Logical Range composition and execution. This document assumes the existence of such supporting tools.

Object Model View

The TENA Object Model and associated services and standards provide the foundation for the Logical Range paradigm. The TENA Object Model represents a view of test and training exercises in terms of common objects (e.g. terrain, personnel, platform, and environment) and their interactions. It is composed of class definitions for objects which are characterized by attributes (descriptive information) and methods (functions that can be performed). The TENA Object Model is presented in a hierarchical graphical structure in Figure 4, and will be repeated at each phase of a sample exercise life cycle

view with some of the corresponding classes, attributes, and methods highlighted to emphasize appropriate model components.

The TENA Object Model top-level class descriptions are:

- *Customer* - Represents the requirement to conduct an exercise and establishes criteria for the planning, scheduling and evaluation of the exercise. The customer can assess, observe and control the exercise. The customer receives a cost estimate for the exercise or test and commits the exercise or test based on that estimate and the available budget. The customer receives a customer data package at the end of the exercise or test reflecting the data gathered and evaluated at the test points covered during the conduct of the exercise or test.

Figure 4. Top-Level TENA Object Model

- *Logical Range Support Tool* - Represents the mechanisms required to define, plan, schedule and execute a Logical Range Exercise. The Logical Range support tool set provides the ability to browse Logical Range resources and scenarios and execute required support functions.

- *Logical Range Test/Training Exercise* - Actions required to conduct an exercise using a Logical Range. The Logical Range Test/Training Exercise is driven by a

set of test plans and schedules, resulting in a customer data package for evaluation and review.

- *Logical Range Scenario* - A specific composition of resources to support a Logical Range exercise.
- *Mission Space* - This comprises the primary resources that are the focus of the Logical Range scenario:
- *Participant* - *Platform*, *weapon*, or *person*
- *Environment* - *Natural*, *tactical*, *political*, or *doctrinal*
- *Event*(s) - Scenario conditions (e.g. proximity, time, signal threshold, etc.)
- *Logical Range Resources* - Represents all of the secondary resources and logistics (internal assets that are TENA compliant) available to a Logical Range test/training exercise from open air ranges, HITL, ISTF, integration labs, measurement facilities, and simulation facilities.

Logical Range Business Process Model View

The Logical Range Business Process Model [TENA,3] provides a comprehensive look into the organizational and procedural activities from the perspective of the Logical Range users and managers. The model defines the process activities and their inputs, outputs, methods, and controls at hierarchical levels of detail. Analysis of the developed model provides insight into process problems and improvement options for implementing and supporting the Logical Range. It suggests the need for tools and/or processes to address problems involving schedules, logistics, component substitution, and other areas. Figure 5, presents the LRBPM node diagram depicting the five different phases of conducting a Logical Range exercise. These phases are also common to current test and training facility operations, and consequently, any tools developed to automate portions of this process will likely support existing operations as well. As with the TENA Object Model, the corresponding LRBPM Diagrams will be repeated at each phase of the sample exercises to emphasize appropriate model components.

The LRBPM was developed to enable the business processes that pertain to building and using a Logical Range. It supports all phases of test and training conduct. The LRBPM provides a standard process that maintains current test and training business process integrity and functionality, but allows for distributed, multi-site, and multi-Service exercise development.

Figure 5. LRBPM Node Diagram

The LRBPM is a customer and scenario based process. A customer is defined as a person, command, or organization that has a need to sponsor a test or training exercise. A scenario is the combination of environment, participants, events and resources that can be used to meet the test or training customer requirements. In the LRBPM the customer has control of all the activities and collaborates in the scenario definition, planning, scheduling, executing and reviewing phases of the Logical Range test or training exercise. A scenario is one viable way of meeting customer requirements. There could be one or more viable scenarios. The Logical Range scenario is the particular scenario selected to be utilized for planning of a specific instance of a Logical Range. The Logical Range scenario is composed of a mission space definition and Logical Range resources.

The LRBPM commences with inputs of customer requirements and concludes when a customer data package is delivered. The LRBPM imposes no time constraints on the instantiation of a Logical Range. It allows for iterative activities to revisit earlier steps in order to change parameters or adjust specifications.

Logical Range Application Concept Notional Example

The following example will be illustrated by following the five major LRBPM phases and noting the object classes used in the TENA Object Model. Figures containing both the LRBPM diagram and TENA Object Model will accompany each phase description. To show the objects used for each phase, the object boxes will be shadowed and the lines connecting those will be wider. In the text explanation object classes will be italicized. Often, throughout the different phases a set of object classes is used for multiple purposes, however different attributes and methods are invoked depending of the nature of the activity. For example, the object class *environment_terrain* is used by the Define Scenarios activity to determine if a particular terrain exists. The same object class *environment_terrain* is used by the Determine Cost Estimate activity but it will look

at the cost attribute instead of the existence of the object.

The Logical Range environment offers great flexibility to test and training conduct as a variety of customer test and/or training objectives can be addressed through minor variations, resulting in several similar Logical Range scenarios. Each scenario is treated similarly with slightly different scenario and component selections. Our notional example will illustrate how various scenarios are generated from a set of scenario characteristics based on customer requirements. The notional example is a simplified test exercise.

Notional Example:

A customer has the objective of evaluating the drive train of a field-ready tank for traction and durability. He wants to compare different scenarios to determine a cost-efficient alternative to conduct his test. He would like to consider any combination of virtual, constructive, and real scenarios that will minimize test runs, thus minimizing costs.

Phase 1. Define a Logical Range Scenario:

Figure 6, shows the LRBPM Phase 1, Define a Logical Range Scenario and the TENA Object Model shadowed object boxes that are used during this phase. Throughout Phase 1, the same objects are used, however different attributes and methods are invoked. Through Logical Range manager interaction with the customer, objectives are translated into characteristics for the exercise mission space (participants, environments, and events). The participants include personnel, platforms and weapons. Environments can be natural, tactical, political, or doctrinal. Events refer to either a scripted timeline or conditional events of a free play environment. This information is then presented in the form of one or more viable Logical Range scenarios that can be matched to available assets and capabilities for exercise feasibility and cost comparison. This phase can provide valuable information for future capability planning, as unmatched requirements will be documented for later use by range management.

First, we must define the scenario characteristics of our example. This first activity involves the *Customer,* the *Logical Range Support Tool, Logical Range Test/Training Exercise,* and the *Logical Range Scenario* objects. During this activity the acceptable boundaries or specifics that the Logical Range Scenario will use to meet customer requirements are determined.

Figure 6. Phase 1: Define Logical Range Scenario

These boundaries are selected as inputs, ranges or limits for the construction of the scenarios. Table 1, shows some of the scenario characteristics for our example.

Table 1. Scenario Characteristics

Objective	Evaluate the drive train of a field-ready tank for traction and durability
Participants	Tank
Environment	Terrain, 60degree, 200 foot dry sand hill

Events	Three minutes to ascend, turn while on slope, and descend - measurements with .5fps and .2dps accuracy
Type	(Test/Training) Test
Service	(Army/Navy/Air Force/Marines/Joint) Army
Sponsor	Army Organization
Priority	Pre-set priority level
Scheduling Limitations	Timeline (June-Sep 1998)
Financial Limitations	Not to exceed xx dollars

Using the Logical Range Support Tool, the Customer enters the scenario characteristics and requests scenarios to be defined. The Logical Range Test/Training Exercise, Logical Range Scenario, and the Mission Space (Participant, Environment, and Event) objects are used to develop candidate scenarios that will satisfy customer requirements based on the scenario characteristics entered. The following tables present the notional candidate scenarios for our example as well as expected results, benefits and the rationale that supports their use.

The Logical Range offers the flexibility to change parameters in order to meet customer requirements. For example, the customer could decide that in addition to the dry sand hill he also needs to test in a muddy terrain. This information could be easily entered and a new set of candidate scenarios developed. At this point, the customer could request asset or scenario specific information, to include location, cost, lessons learned, schedules, and capability descriptions.

Table 2. Scenario A

Scenario A	Simulated tank on simulated hill
Participants	Simulated Tank
Environment	Sand Dune simulation
Planning Events	Simulation run for 5,000 trials
Data Package	Develop expected ranges of test data, expected and list of possible deviations
Expected Results	Run simulation multiple times to produce expected live test data range and thresholds as well as possible anomalies
Benefits	Simulations provide expected results and help to establish live test parameters (e.g., the minimum number of test runs necessary for a specific test confidence level), and identify possible test points of special interest The use of simulations will greatly reduce the total cost of the entire test process
Rationale	This simulation will provide important data as to the expected performance of the tank. Information gathered during the live test will be used to improve the fidelity of the tank and sand dune models

Table 3. Scenario B

Scenario B	Real tank on simulated hill
Participants	Real Tank
Environment	Sand Dune simulation
Planning Events	While running in the neutral gear, on a flat level surface, exercise the drive train by increasing and decreasing the Rpm's as would be expected for a real transit of a 60 degree slope. Exercise simulation using scenario characteristic events; run for 1,000 trials
Data Package	Develop unloaded drive train baseline of expected ranges of test data, expected and list of possible deviations
Expected Results	Run combined simulation and live test multiple times to produce baseline test data for an unloaded drive train range and thresholds as well as possible anomalies
Benefits	This combination of Simulation and real testing will provide baseline data, which will be used along with expected results developed during a simulation to help to establish live test parameters (e.g., the minimum number of test runs necessary for a specific test confidence level), and identify possible test points of special interest

	The use of combined simulations and live tests will greatly reduce the total cost of the entire test process
Rationale	This combined simulation live test will provide important baseline data as to the expected performance of the Tank Information gathered during the combined simulation and live test will be used to improve the fidelity of the tank and sand dune models

Table 4. Scenario C

Scenario C	Real tank on a tilt table
Participants	Real Tank
Environment	Tilt Table
Planning Events	While running in the neutral gear, tilt the tank from 0 degrees to +60 degrees, back to 0 degrees to –60 degrees – cycle to be completed in three minutes. Repeat the test 100 times – at each change in slope (-60,0,+60 degrees)
Data Package	Collect drive train torque and temperature data
Expected Results	Run test 100 times to determine if the attitude of the tank contributes any measurable change to the unloaded performance of the drive train
Benefits	This tilt table test will help to establish any effects caused by the orientation of the tank irrespective of the drive train load This test further reduces the total live test steps necessary to reach the level of confidence required by the customer
Rationale	This series of tests will determine if the attitude of the tank has any impact on the performance of the drive train. Information collected during these tests will be analyzed to determine modifications to the expected data derived from the simulation runs. Information gathered during these tests will be used to improve the fidelity of the tank

	and sand dune models

Table 5. Scenario D

Scenario D	Real tank on a tilt table, under environmentally controlled conditions
Participants	Real Tank
Environment	Tilt Table, within a climatically controlled environment
Planning Events	While running in the neutral gear, tilt the tank from 0 degrees to +60 degrees, back to 0 degrees to –60 degrees – cycle to be completed in three minutes. Repeat the test 50 times, at each of 4 temperature levels (-40 C, 0 C, 20 C, and 40 C), and at 3 different ambient humidity levels for each temperature (0%, 50%, and 100%), at each change in slope (-60,0,+60 degrees)
Data Package	Collect drive train torque and temperature data
Expected Results	Run test 50 times for each temperature range and humidity level (a total of 600 tests) to determine if the operating environment of the tank contributes any measurable change to the unloaded performance of the drive train
Benefits	This environmentally controlled test will help to establish any effects caused by the operating environment of the tank irrespective of the drive train load This test further reduces the total live test steps necessary to reach the level of confidence required by the customer
Rationale	This series of tests will determine if the operating environment of the tank has any impact on the performance of the drive train. Information collected during these tests will be analyzed to determine modifications to the expected data derived from the simulation runs. Information gathered during these tests will be used to improve the fidelity of the tank and sand dune models

Table 6. Scenario E

Scenario E	Real tank on a real hill
Participants	Real Tank

Environment	Open Air Test Track
Planning Events	Execute conceptual scenario events. Repeat the test 100 times.
Data Package	Collect drive train torque and temperature data
Expected Results	Run test 100 times analyze data collected and compare to expected results from simulations and tilt table test.
Benefits	Because of the use of simulations and tilt table tests, the number of the most expensive live test has been greatly reduced saving the customer significant testing dollars.
Rationale	This series of live tests will directly address the customers requirements and provide a complete evaluation analysis, comparing expected simulated data with insitu and live test data. Information gathered during this live test will be used to improve the fidelity of the tank and sand dune models.

The Logical Range Support Tool will browse the Logical Range Asset Catalogue to match the scenario requirements are matched to facilities and ranges capabilities. If requirements cannot be matched, an Unmatched Requirements report will be created. The same objects used during the previous activity will be used, however a lower level of detail will be added in the next step. These objects are in the *Mission Space* area of Figure 4. In our example we need to add to the *Participant* class*, a Platform,* to the *Environment* class*,* and a *Natural Environment.* For example, Scenario A has a simulated tank in the *Participant_Platform* class. A matched capability will then be an instance of the *Participant_Platform* class, or in our case a particular Tank. The particular Tank class will contain specific information regarding location, cost, and schedule.

Table 7. Matched Requirements

Candidate Scenarios	Matched Requirements	Matched Capability
Scenario A	Simulated tank on simulated hill	1. Tank Simulation A and Hill Simulation B 2. Tank Simulation E and Hill Simulation C
Scenario B	Real tank on simulated hill	1. AB Tank and Hill Simulation B 2. CD Tank and Hill Simulation C
Scenario C	Real tank on a tilt table	1. AB Tank and XY Tilt Table 2. CD Tank and WY Tilt Table
Scenario D	Real tank on a tilt table, under environmentally controlled conditions	1. AB Tank, XY Tilt Table, and a Climatic Chamber 2. CD Tank, WY Tilt Table, and a Climatic Chamber
Scenario E	Real tank on a real hill	1. AB Tank and Real Hill at XYZ Proving Grounds 2.

		CD Tank and Real Hill at ABD Proving Grounds

The matched capabilities will be used to develop a cost estimate. Cost information is also found in the Logical Range Asset Catalogue and available through the Logical Range Support Tool.

The implementation scenario will constitute the Logical Range scenario that will be used for the planning of the test or training exercise. The selected LR scenario will contain specific matched capabilities that will become primary requirements. These primary requirements are the high-level and essential capabilities that are needed to satisfy customer requirements. For example, Scenario D requires the use of a real tank, a tilt table, and environmentally controlled conditions. These requirements were matched with an AB or CD Tank, a XY or WY Tilt Table, and a Climatic Chamber. If we fail to schedule any of these primary requirements, we will need to change our scenario or scheduling window. These primary resources are called Logical Range Schedule Requirements and are an input to the next major activity of the LRBPM, Schedule Logical Range. For our example, we will select Scenario E.

Benefits of Define Logical Range Scenario Phase:

- Assess test objectives and specifications against broad range of available resources.
- Access and compare historical resource cost and performance characteristic information.
- Capability of changing parameters to accommodate a broader variety of scenarios.

Phase 2. Schedule Logical Range

Once the customer selects a Logical Range scenario, the primary mission space resources (participants, environment, and events) can be scheduled based on priority and availability at the Joint, Service, and Range/Facility levels. This phase is iterative due to dynamic schedules and associated contingency planning. Logical Range support tools will provide scheduling access to the mission space object availability and priority attributes. The Logical Range Scenario E is composed of a real tank and a real hill. These are the primary schedule resources that need to be scheduled in order to successfully conduct our test. Figure 7, illustrates the LRBPM steps followed and the objects corresponding to the *mission space* that are used. Note that one of the attributes of the *Tank* and *Terrain* objects is "Schedule."

Figure 7. Phase 2: Schedule Logical Range

Logical Range support tools will allow the Logical Range manager to optimize the schedule by performing resource substitution and "what if" analysis. Once schedule requests have been acknowledged and tentatively approved by appropriate mission space managers, a Logical Range working schedule is established. As a working schedule, it is subject to change as detailed plans evolve and the exercise execution phase approaches.

Additional information could be entered at this point that will aide the scheduling process. For example, one of Scenario D's Primary Schedule Requirements is an AB or CD Tank. Since there are more fielded AB tanks we would prefer to schedule this kind of tank in particular. Therefore, an additional criteria for our scheduling process will be to restrict the search to AB tanks only. The Logical Range Support Tool will be used to create a report which will contain information regarding each of the Primary Schedule

Resources availability. The Primary Resources Availability Report is then used by the LRST optimization tool to develop an optimized schedule that will be called the LR Working Schedule. It will also generate the LR Resources assignment which will make the time commitment to each Mission Space resource.

Benefits of the Scheduling Phase:

- Match test objectives and specifications to most appropriate available resources from community wide inventory.
- Assess resource cost and performance characteristics.
- Create productive partnerships by identifying resources that compliment each other.

Phase 3. Plan

Figure 8, depicts the TENA Object Model components included in the planning phase as well as, the process followed by the LRBPM. During the planning activity the financial documentation is established, and Secondary and Support Requirements are defined, coordinated and documented in the Logistics Annex. Finally, the LR Plan is compiled and a refined cost estimate is developed. This phase involves a lower level of detail in the *Logical Range Resources* object class. In our example, the scenario chosen called for the *Open Air T&E/Training Range* object class. *Secondary Resources* are the *Sensors* that will be used to measure the traction and durability of the drive train of the tank. The *Logistics* class includes *Financial, Communications, Computers,* and *Personnel* assets. Note that the first step in the LRBPM, Establish LR Operating Financial Environment, will use the *Financial* object. The second and third LRBPM steps will use lower level of both *Secondary Resources* and *Logistics* classes. For example, a *mechanical sensor* object will be instantiated to measure the pressure of the drive train and these information will be processed by an *Analyzer* assigned to run on a *Computer*. Finally, the compiled Logical Range Plan will be saved in the *Logical Range Test/Training Exercise* object.

Figure 8. Phase 3: Plan

Benefits of Planning Phase:

- Select exercise scenario components from broad range of available resources.
- Perform scheduling substitutions to accommodate resource limitations.
- Perform scenario modifications to accommodate resource limitations.
- View/maintain scenarios and schedules for facilities and resources.
- Remotely participate in scheduling conferences.

Phase 4. Execute Plan

Figure 9, depicts the same object model instance presented during the planning phase. This time the objects' operations will be invoked in order to execute the plan. During execution the Logical Range plan will be followed commencing with pre-exercise setup and concluding with a debrief. Setup will include final initialization of assets in preparation for starting the exercise. It will also include testing and/or calibration of assets and connectivity, initialization of log and monitor activities, contingency actions regarding asset substitution and scenario modifications, and final review of command and control issues. The exercise will follow the plan with real time adjustments whether anticipated or the result of free play. Debrief will include presentation of results during and following the exercise.

Figure 9. Phase 4: Execute Plan

Benefits of Execution Phase:

- Provide distributed cost accounting for resources of entire test/training community.
- Access resource cost and performance characteristics.
- Perform scenario management and reuse.
- Create and maintain a consolidated comprehensive Logical Range exercise plan.

Phase 5. Closeout

Figure 10, illustrates the Closeout phase which mostly includes the *Logistics* objects are instantiated to support the closing phase. At conclusion of the execution phase of the Logical Range Test/Training Exercise it is necessary to finalize exercise results, provide an approved data package, collect customer and operations feedback, and conclude financial arrangements. Most exercises don't proceed completely as planned, so the closeout process must be responsive to resolving differences and providing the customer with the most complete results possible and a negotiated final cost. It is also necessary to document and leverage the Logical Range lessons learned so that subsequent exercises have improved measures of effectiveness. A variety of Logical Range support tools will be used during this phase.

Figure 10. Phase 5: Closeout

Benefits of Closeout Phase:

- Promotes faster customer data package delivery and presentation.
- Promotes quality of products.
- Minimizes closing time.
- Promote process improvement in the means of lessons learned.

The TENA Application Concepts document has defined the term *application concept* as the name given to a group of methods or procedures which show how to use architecture components to solve primary customer needs. Three TENA application concepts are identified:

- Logical Range Application Concept
- Systematic Reuse Application Concept
- Continuous Insight Application Concept

The *Logical Range Application Concept* shows how the TENA Object Model structure and the Logical Range Business Process Model work together to respond to the increased demand for multiple-site exercises and/or exercises which cross T&E/training or live/virtual/constructive boundaries. High-level requirements for the Logical Range are identified.

A discussion of a test and training event relates the Business Process Model and the TENA Object Model and identifies some benefits of the Logical Range such as,

- Assess test objectives and specifications against broad range of available resources,
- Assess resource cost and performance characteristics,
- Perform Logical Range plan (scenario, logistics, safety, security, etc.) management and reuse,
- Identify process automation opportunities, and
- Begin execution of a Logical Range exercise from any suitable location with minimal or no special setup required.

TENA Integrated Validation and Verification Plan [TENA,4], calls for an expanded analysis of scenarios via a trace of all architecture component interactions at a detailed level. Future revisions of the TENA Application Concepts document will demonstrate other application concepts.

BoOD	Board of Operating Directors
BPR	Business Process Reengineering
	C4I Command, Control, Communications, Computers & Intelligence
CDAPS	Common Display and Analysis Program
CINC	Commander-in-Chief
CJCS	Chairman Joint Chiefs of Staff

CNO	Chief of Naval Operations
COE	Common Operating Environment
COTS	Commercial-off-the-Shelf
CTEIP	Central Test and Evaluation Investment Program
CTTRA	Common Test and Training Range Architecture
DARPA	Defense Advanced Research Projects Agency
DII	Defense Information Infrastructure
DISA	Defense Information Systems Agency
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
DTTSG	Defense Test and Training Steering Group
DTEC	Defense T&E Complex
HITL	Hardware-in-the-Loop
HLA	High Level Architecture
HWIL	Hardware-in-the-Loop
ISTF	Installed System Test Facility
IV&V	Integrated Validation and Verification
JCS	Joint Chiefs of Staff
JIM	Joint Improvement and Modernization
JMASS	Joint Modeling and Simulation System
JPO(T&E)	Joint Project Office (Test and Evaluation)
JRRC	Joint Regional Range Complex
JSIMS	Joint Simulation System
JTA	Joint Technical Architecture
JTTRR	Joint Test and Training Range Roadmap
JWARS	Joint Warfare Simulation
LRBPM	Logical Range Business Process Model

M&SMP	Modeling and Simulation Master Plan
MAIS	Major Automated Information Systems
MDAP	Major Defense Acquisition Programs
MRTFB	Major Range & Test Facility Base
NUWC	Naval Underwater Warfare Center
OAR	Open Air Ranges
OM	Object Model
OSD	Office of the Secretary of Defense
	OT&E Operational Test and Evaluation
	PDUSD(A&T) Principal Deputy Undersecretary of Defense (Acquisition & Technology
PE	Program Element
PLA	Product-Line Approach
RCC	Range Commanders Council
RDT&E	Research, Development, Test & Evaluation
SEI	Software Engineering Institute
SETI	Synthetic Environment Training Initiative
STEP	Simulation, Test and Evaluation Process
SWIL	Software-in-the-Loop
T&E	Test and Evaluation
TEMS	Test & Evaluation Modeling & Simulation
TENA	Test and Training ENabling Architecture
TERC	Test and Evaluation Resource Committee
TERIB	Test and Evaluation Reliance Investment Board
TIRIC	Training Instrumentation Resource Investment Committee
USD(A&T)	Under Secretary of Defense (Acquisition & Technology)
VTTR	Virtual Test and Training Range

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