Range Commanders Council

DATA SCIENCES GROUP

TEST AND EVALUATION (T&E) METADATA REFERENCE MODEL

WHITE SANDS MISSILE RANGE
REAGAN TEST SITE
YUMA PROVING GROUND
DUGWAY PROVING GROUND
ABERDEEN TEST CENTER
ELECTRONIC PROVING GROUND

NAVAL AIR WARFARE CENTER WEAPONS DIVISION, PT. MUGU
NAVAL AIR WARFARE CENTER WEAPONS DIVISION, CHINA LAKE
NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION, PATUXENT RIVER
NAVAL UNDERSEA WARFARE CENTER DIVISION, NEWPORT
PACIFIC MISSILE RANGE FACILITY
NAVAL UNDERSEA WARFARE CENTER DIVISION, KEYPORT

30TH SPACE WING
45TH SPACE WING
AIR FORCE FLIGHT TEST CENTER
AIR ARMAMENT CENTER
ARNOLD ENGINEERING DEVELOPMENT CENTER
BARRY M. GOLDWATER RANGE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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DOCUMENT 176-11

TEST AND EVALUATION (T&E) METADATA REFERENCE MODEL

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Prepared by

DATA SCIENCES GROUP (DSG)

Data Management Committee (DMC)

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PREFACE

This document was prepared by the Data Sciences Group (DSG), Data Management Committee, of the Range Commanders Council (RCC) under task number DS-04. This document is to be the reference model across all test and evaluation (T&E) centers. The model defines the metadata content required to completely describe the T&E data life cycle and the relationships between that content while defining accepted standard terminology. It must be sufficiently detailed to map to site-specific metadata data-sets. This will lay the foundation for a metadata standard at all ranges to assist in commonality.

The RCC would like to thank the Data Management Committee for the hard work in developing this document.

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ACRONYMS

AEDC	Arnold Engineering Development Center
AFB	Air Force Base
AFFTC	Air Force Flight Test Center
ATEC	Army Test and Evaluation Command
CTDMP	Comprehensive Test Data Management Program
CTEIP	Central Test and Evaluation Investment Program
DMC	Data Management Committee
DoD	Department of Defense
DPG	Dugway Proving Ground
DSG	Data Sciences Group
I&M	Instrumentation and Modernization
IEEE	Institute of Electrical and Electronics Engineers
IHAL	Instrumentation Hardware Abstraction Language
iNET	integrated Network Enhanced Telemetry
IRIG	Inter-range Instrumentation Group
ITC	International Telemetering Conference
JMETC	Joint Mission Environment Test Capability
KBSI	Knowledge Based Systems, Inc.
MDL	Metadata Description Language
MISG	Motion Imagery Standards Group
NUWCDIVKPT	Naval Undersea Warfare Center Division Keyport
OWL	Web Ontology Language
RCC	Range Commanders Council
SBIR	Small Business Innovative Research
T&E	test and evaluation
TEML	T&E Markup Language
TEMPL	T&E Metadata Plaza
TEMRL	T&E Metadata Reference Model
TENA	Test and Training Enabling Architecture
TMATS	Telemetry Attributes Transfer Standard
UML	Unified Modeling Language
WSMR	White Sands Missile Range
XML	eXtensible Markup Language
YPG	Yuma Proving Ground

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CHAPTER 1

BACKGROUND

1.1 Purpose

The purpose of this document is to describe the Test and Evaluation Metadata Reference Model (T&E Ref Mod) developed by the Data Sciences Group, Range Commanders Council under task DS-04. This document was developed in concert with *RCC Document 175-11 T&E Metadata Best Practices* (Reference a).

1.2 Need for a Metadata Reference Model

Modern test and evaluation efforts produce large amounts of information external to the actual measurements being acquired, such as test requirements, descriptions of the test article, data format descriptions, and much more. Maintaining access to and understanding this metadata is crucial to understanding the data itself, especially when test data must be revisited months or even years after a test is completed. The value of the original data is diminished without the metadata. The ability to review all of the metadata associated with a past test provides a complete picture of the circumstances under which the data was gathered. Therefore, the analysis of the older data will be easier and more effective.

Currently, the terminology used to describe this metadata, the formats used for storing it, and the methods and technologies used to access metadata vary widely from one organization to another. This makes it difficult to share metadata (and by extension, data) between organizations, and introduces a steep learning curve for personnel moving between organizations. Despite these differences, the tasks performed, and the types of information captured, are the same.

Knowledge of this metadata is held only by those involved in that phase of the process. Thus, there is rarely a single person who holds global knowledge about the types and locations of all metadata recorded for a test. This makes it difficult to assemble in one place a complete set of metadata for a test. Consequently, this metadata reference model has been developed to serve the following purposes:

a. To capture, at a global level, the types of metadata required to completely describe a test.
b. To provide a common terminology that can be used when sharing data and metadata among organizations.
c. To serve as a guideline for test organizations to ensure a more comprehensive capture of metadata.
d. To enable and guide the development of T&E Metadata management systems by providing a common high-level information model.

While smaller-scoped efforts do exist, no prior effort has documented a complete list of the metadata captured by a range for a test.

1.3   Scope

The scope of this document is "T&E Metadata." The most general definition of metadata is "data about data." For this effort, we define "T&E data" to be the actual acquired measurements from a test. In Reference b, T&E Metadata is defined as follows:

> *"T&E metadata is any information that provides additional description or context to the T&E data. This covers a broad spectrum of information, ranging from the initial requirements and motivation for the test, to the test article and instrumentation modifications required to perform the test, to the description of the packet format in which the data is transported."*

This includes requirements, test plans, safety reports, instrumentation hardware descriptions, measurement lists, TMATS files, etc.

The breadth of this effort is the complete set of T&E metadata as described above. In comparison, the depth is relatively small. The model described herein is meant to be abstract enough to be relevant for all T&E organizations, regardless of the type of article being tested, the systems being used, or the geographical location of the test.

CHAPTER 2

METHODOLOGY

2.1   Methodology

The research for and documentation of this model was assisted by a Phase II Small Business Innovative Research (SBIR) Project funded by Edwards AFB and carried out by Knowledge Based Systems, Inc (KBSI). This ongoing project, named "T&E Metadata Plaza", or "TEMPL," seeks to develop a methodology and a suite of tools to better manage diverse types of T&E metadata (Reference c).

Developing the T&E Ref Mod consisted of the following major activities:

a. Information Gathering.
b. Coordination with the committee.
c. Development of the model.

2.2   Information Gathering

In order to gather the information necessary to develop the model, we visited a diverse set of T&E centers across the country and discussed current metadata artifacts, practices, and issues with the various metadata developers and users at each site. Over the course of 4 months, one or two members of the KBSI project team visited 7 different test centers. Table 2-1 lists the facilities that were visited, the date each facility was visited, and key points of contact.

TABLE 2-1. TEST CENTER VISITS				
Service	**Facility**	**POC**	**Trip Date**	**KBSI Attendees**
Air Force	Edwards AFB	Charles Jones	4/15/2010	John Hamilton Tim Darr
NASA	NASA Dryden	Robert Harvey	4/16/2010	John Hamilton Tim Darr
Army	Yuma Proving Ground	Jason Kaza	6/7/2010	John Hamilton Byon Williams
Commercial	Boeing	Lee Eccles	6/15/2010	John Hamilton Byon Williams
Army	Aberdeen Proving Ground	George Bartlett	6/29/2010	Byon Williams
Navy	Keyport	David Quick	7/13/2010	John Hamilton Byon Williams
Navy	Patuxent River	Eric Harvey	7/26/2010	John Hamilton Byon Williams
Army	White Sands Missile Range	Dave Salas	8/3/2010	John Hamilton Byon Williams

During each visit, the KBSI members met with several different groups within the organization. These groups were organized by the primary point of contact for each facility, but were typically grouped according to their role in the test process.

Each group was asked to describe their typical test process. During each of these process descriptions, the specific metadata artifacts that were created, modified, or used at each step were documented in a "data dictionary" spreadsheet, which was used to develop the model as described in a later section.

2.3   Coordination between KBSI and the Data Management Committee

Throughout this effort, KBSI conducted monthly teleconferences with members of the Data Management Committee to review changes to the model and solicit feedback. Additionally, a collaboration website (share.kbsi.com) was set up where committee members could weigh in on the progress of the model development between meetings. The coordination site included the following major components:

    a. A document repository where the current model as well as minutes and records from all meetings were kept.
    b. A discussion forum where committee members can post questions and feedback regarding the model and the model development effort.

2.4   Development of the Model

The process flow followed to construct the T&E Ref Mod is illustrated in Figure 2-1. First, the results from each interview were compiled into a data dictionary. Each data dictionary was documented in the form of a spreadsheet with columns that list the name of each metadata artifact, a description of it, and the types of information contained in it.
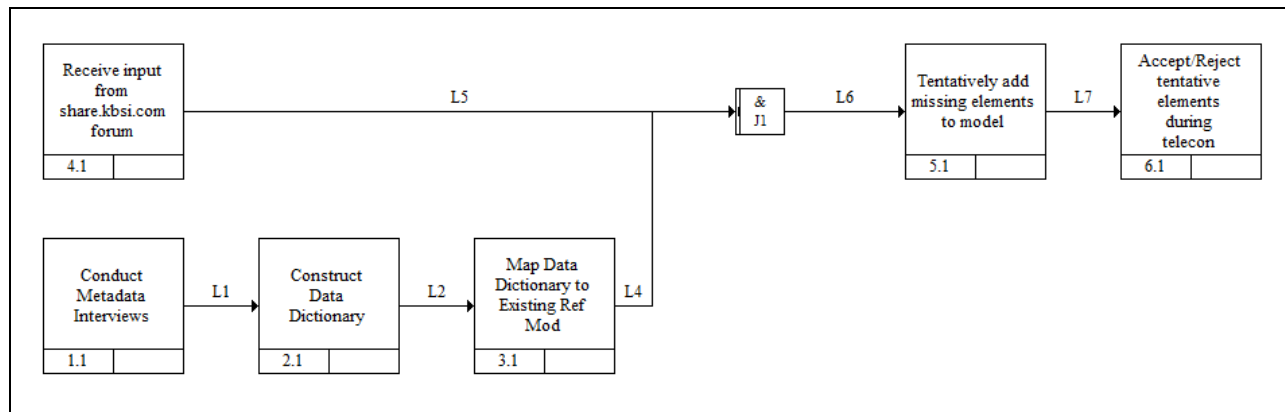

Figure 2-1. T&E Ref Mod Modification Process Flow.

The artifacts in the data dictionary were then mapped to existing Ref Mod elements. An additional column was added to each data dictionary that lists the Ref Mod element(s) that are equivalent to the types of information stored in each artifact. This mapping process quickly exposed missing or misnamed elements in the model. The committee then composed the reference model based not only on this mapping process but also on comments received from forums on the working group portal. Finally, the changes were presented to the working group during one of the regular teleconferences, where each modification was either accepted or rejected by the group.

2.5 Format and Documentation of the Model

Three deliverables have been developed based on this effort:

a. A Unified Modeling Language (UML) Class Diagram of the T&E Ref Mod: Reference d provides a graphical picture of the model and is ideal for display. The UML class diagram also enables the usage of software tools which can automatically generate object model source code for use in software applications.

b. An Ontology of the T&E Ref Mod, in the Web Ontology Language (OWL) format. The ontology provides a more structured logical description of the model and its relationships (see Reference e). By representing the T&E Ref Mod as an ontology, machine-readable rules can be embedded into the model. Automated reasoning systems can then execute these rules to extract information and perform any number of advanced operations such as automated metadata validation and metadata traceability (Reference f).

c. This document. Provides a description and context of the model.

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CHAPTER 3

UTILIZING THE MODEL

The model itself has value both as a common terminology and as a description of the complete set of T&E metadata. Additionally, the model can be used as the basis for developing future metadata management systems such as those addressed in the *T&E Metadata Best Practices* document (Reference a).

3.1   The TEMPL Methodology and Architecture

Hamilton et al. describe the TEMPL methodology and architecture in (Reference b). The TEMPL approach combines the T&E Ref Mod with organization-specific data and process models to enable:

    a. Metadata browsing, search and retrieval.
    b. Metadata repository construction.
    c. Verification, Validation, and Completeness (VV&C) checking.

The TEMPL architecture is illustrated in Figure 3-1. In this approach, the T&E Ref Mod is mapped to data and process models developed for a specific organization's metadata systems. Embedded in the data models is enough information to enable retrieval of the metadata stored by the organization. The TEMPL middleware can then use these mappings to access the metadata in its native location and display it to the user within the context of the T&E Ref Mod. The various models enable the user to browse and search metadata using either T&E Ref Mod (common) terminology or their own site-specific terminology reflected in their site-specific data and process models. Reference b provides a detailed explanation of the individual TEMPL architecture components as follows:

> *"The architecture can be divided into four layers – knowledge capture, management, and user interfaces; information management; middleware; and data and metadata storage, or persistence.*
>
> *The knowledge capture and user interfaces layer includes KBSI's ModelMosaic® enterprise modeling tool (which includes ontology and process modeling, as well as supporting mapping relationships between them) and the T&E metadata portal and search tools. The portal represents the single interface through which end-users can issue searches, build repositories, and perform verification, validation, and completeness checking against all available metadata.*
>
> *The information management layer consists of the "business logic", including the Verification, Validation, and Completeness checking logic; indexing, search and retrieval engine; and automation logic in ModelMosaic®. Included in the information management layer are various verification, validation and completeness checkers that test various T&E metadata rules. These VV&C checkers support various use cases that perform model and metadata verification, validation, and completeness tests and auto-*

generate models and artifacts. These components are intended to reduce the cognitive workload of the various stakeholders and users of a test program.
The data access middleware layer uses the various models, mappings, database connections, and application program interfaces (APIs) to provide metadata retrieval and navigation services to the information management layer. This engine provides support for mixed-mode (structured and unstructured) data access. The middleware is 'configured' by the models and mappings discussed in later sections. Additionally, by providing a common view into the diverse sources of metadata in the persistence layer, this model-based middleware can be used to support end-user applications not explicitly defined in the TEMPL architecture.

Finally, the user persistence layer consists of the various metadata, ontology and process models, and various mappings, index files for search, rule bases, and sources of data and metadata."

The TEMPL architecture components are shown in Figure 3-1 and described at Reference b.
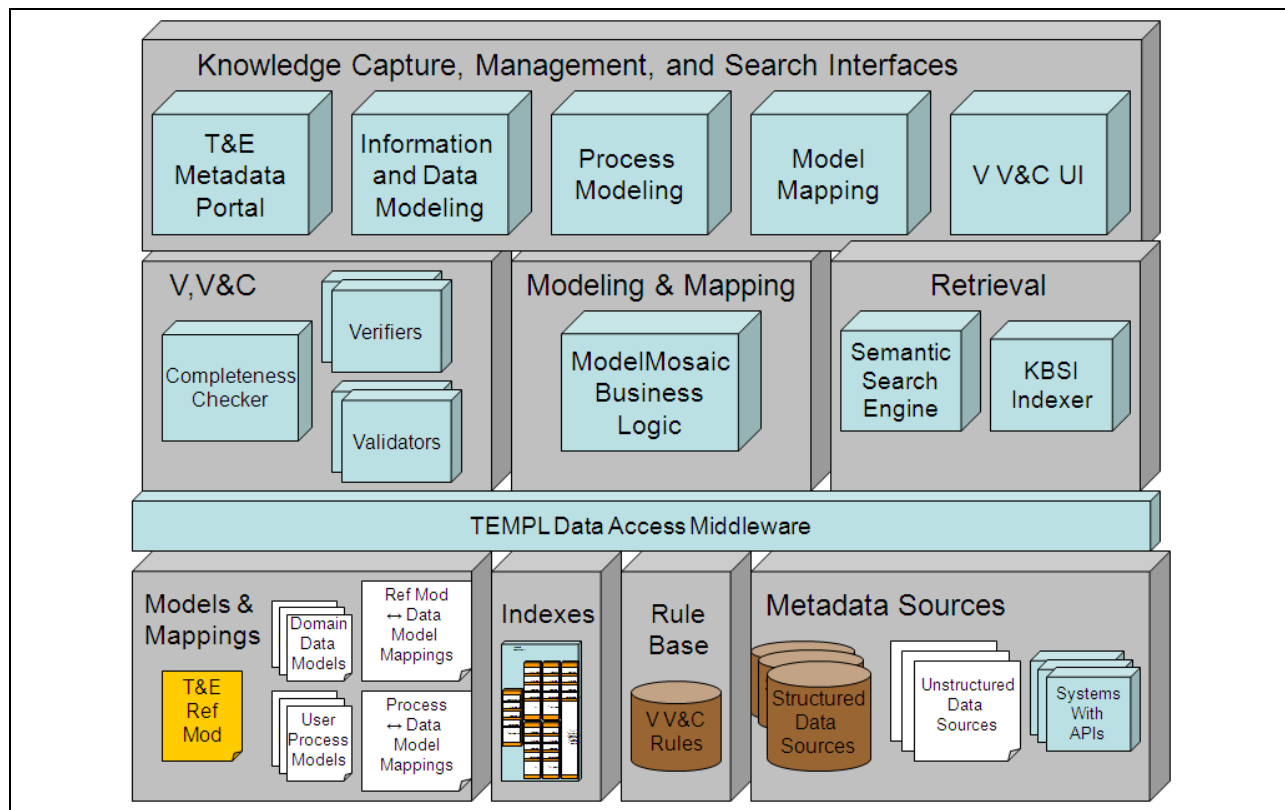

Figure 3-1. High-level TEMPL logical architecture.

3.2   Yuma Proving Ground (YPG): Comprehensive Test Data Management Program (CTDMP)

Yuma Proving Ground has embarked on a CTDMP effort. The core of this program is a tool that provides the identification, storage, and retrieval of low-level test data. This system captures and indexes seven (currently) metadata elements included in the T&E Ref Mod. The CTDMP focuses on a limited scope of test data. The Ref Mod, however, is designed to capture a full range of metadata generated during the T&E process. As a result, the fields that the CTDMP tool utilizes can be directly translated to the T&E Ref Mod. This translation capability should be the case with any system developed for T&E data management, regardless of that system's scope or intended application.

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CHAPTER 4

T&E REFERENCE MODEL

An image of the Unified Modeling Language (UML) Class diagram of the T&E Ref Mod is shown in Figure 4-1. Additionally, the actual UML and Ontology diagrams have been published separately, along with this document.

The T&E Ref Mod is divided into four sections according to the four major aspects of a test. The following paragraphs describe the elements within each section.

T&E Ref Mod Section	Paragraph
Test Center and Test Article Sub-mode	4.1
Project Planning Sub-Model.	4.2
Test Mission Sub-Model.	4.3
Data Reduction and Analysis Sub-model.	4.4
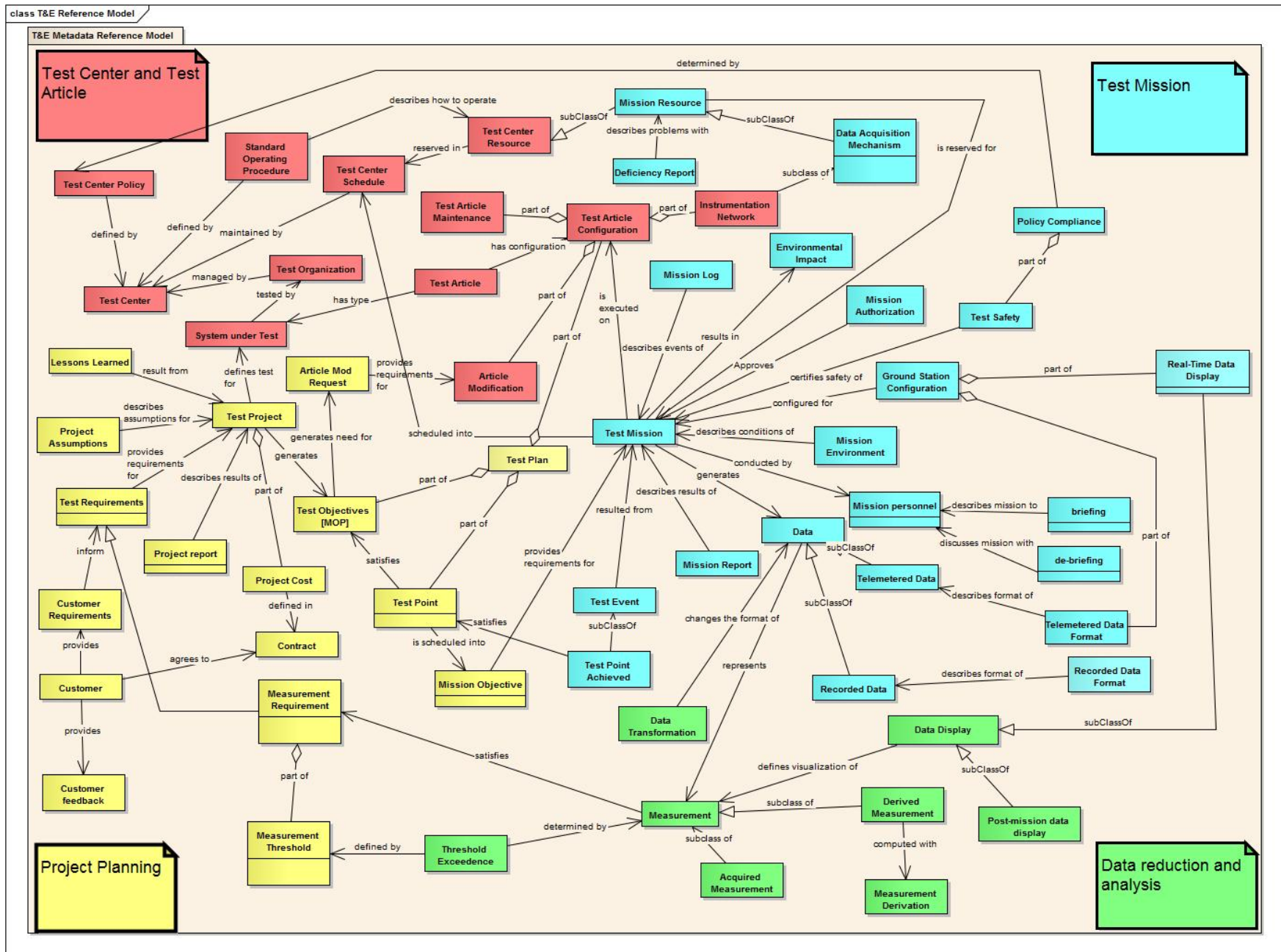
Figure 4-1. UML Class diagram of the T&E Ref Mod.

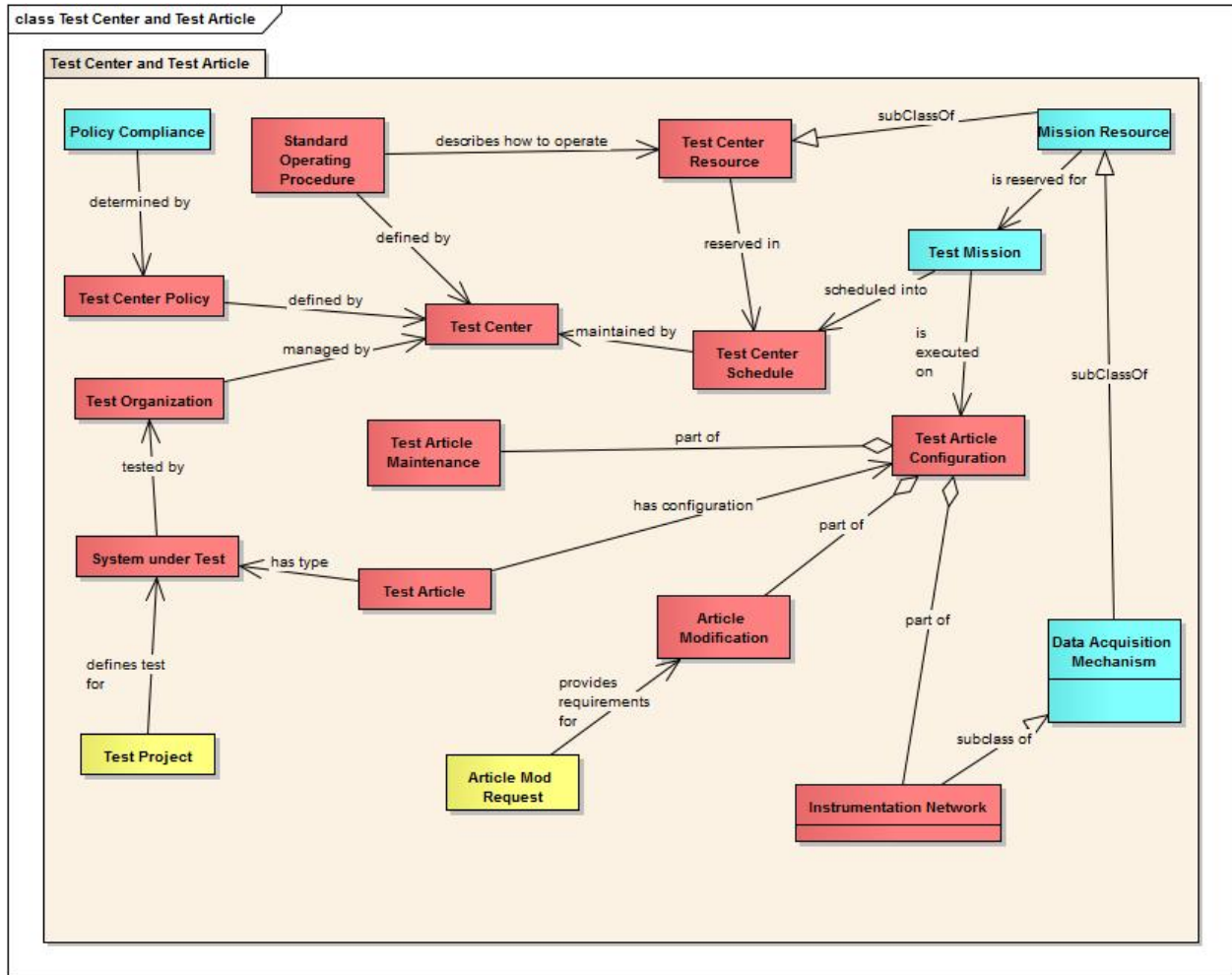## 4.1 Test Center and Test Article Sub-model

Figure 4-2.   Test Center and Test Article Portion of the T&E Ref Mod

The test center and test article section of the model is composed of the following elements:

| TABLE 4-1. ELEMENTS OF THE TEST CENTER AND TEST ARTICLE SECTION OF THE T&E REF MOD	
Element Name	**Definition**
Article Modification	Changes made to the test article to support test objective
Instrumentation Network	Interconnected data acquisition mechanisms
Standard Operating Procedure	Agreed-to policy for operating a particular test center resource
System Under Test	The class(es) or type(s) of the article(s) being tested (such as F16).
Test Article	A specific instance of one of the systems under test (such as a specific tail number)
Test Article Configuration	The settings applied to a test article for a test
Test Article Maintenance	Work required to maintain the test article
Test Center	Command performing the test
Test Center Policy	Guidelines or requirements intrinsic to a specific test center
Test Center Resource	Any discrete asset under the control of the test center
Test Center Schedule	Allocation of test center resources
Test Organization	Division or directorate performing test, subordinate to test center

4.2   Project Planning Sub-model
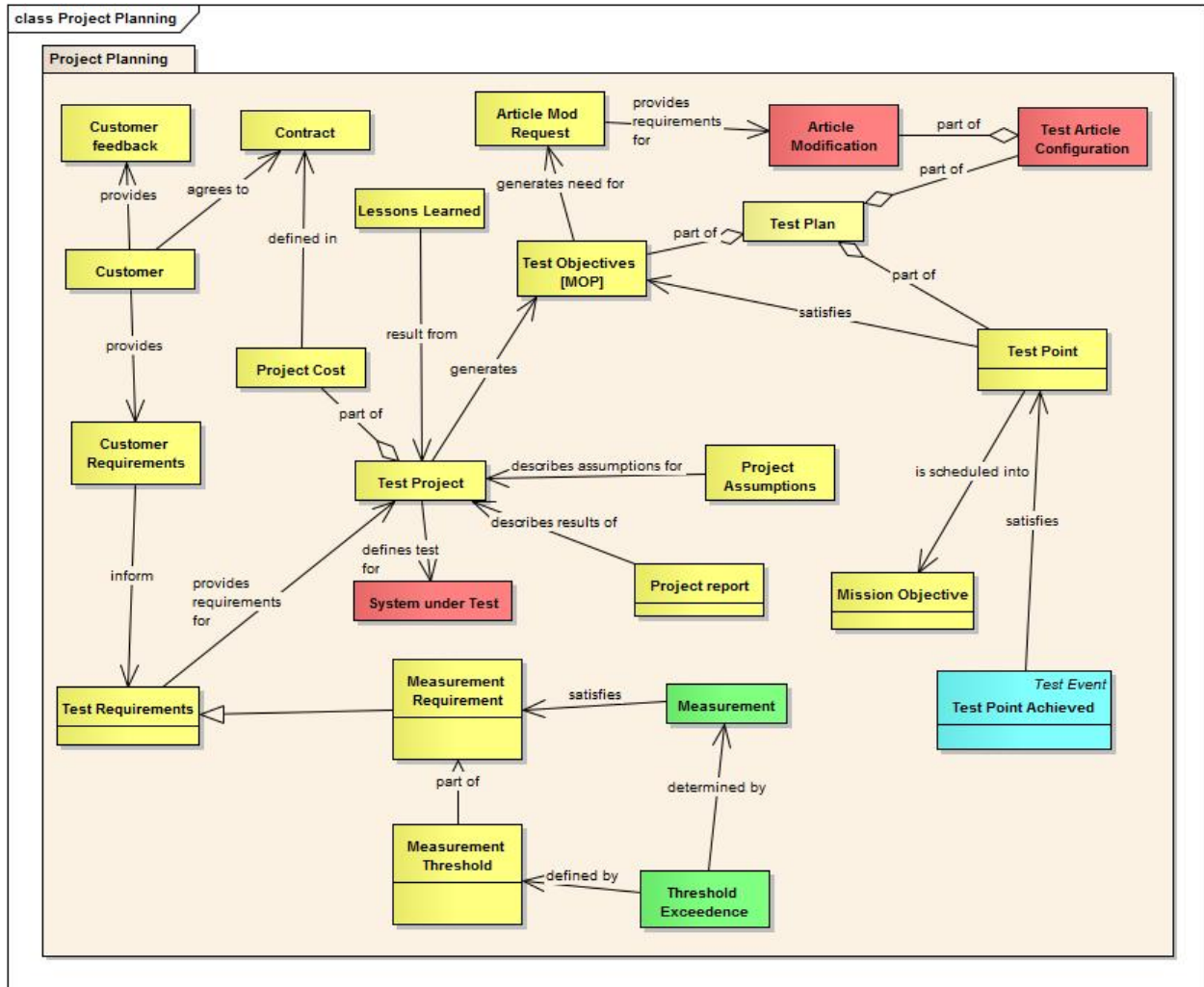
Figure 4-3.   Project Planning portion of the Ref Mod.

The project planning section of the T&E Ref Mod consists of the following elements:

| TABLE 4-2. ELEMENTS OF THE PROJECT PLANNING SECTION OF THE T&E REF MOD	
Element Name	**Definition**
Article Modification Request	Request to change some aspect of the test article in order to set up for Test Objective. For example, a request to install an instrumentation system.
Contract	Document detailing legal relationship between test organization and customer
Customer	Entity commissioning the test
Customer Feedback	Praise/complaints from customer regarding the test
Customer Requirements	Test specifications and deliverables as defined by the customer
Lessons Learned	Knowledge and insight gained by the test
Measurement Requirement	Details about the specific measurements that must be taken during the test to meet the objectives
Measurement Threshold	Defined value limit(s) of interest for a specific measurement
Mission Objective	Description of what is needed from test (such as a flight card)
Project Assumptions	Basis criteria for test planning
Project Cost	Financial resources required
Project Report	Closeout report for test program
Test Objectives	Goals of the test project
Test Plan	Document detailing all actions to be performed for Test Project
Test Point	Specific actions to be performed on/by the test article during the test mission
Test Project	Large scope overall test platform (Army - ADSS; SMC - Cust ID; NASA - SFIA?). E.g. Test Program
Test Requirements	Requirements of the test project as defined by the test organization, in order to meet the customer requirements.

4.3   Test Mission Sub-model
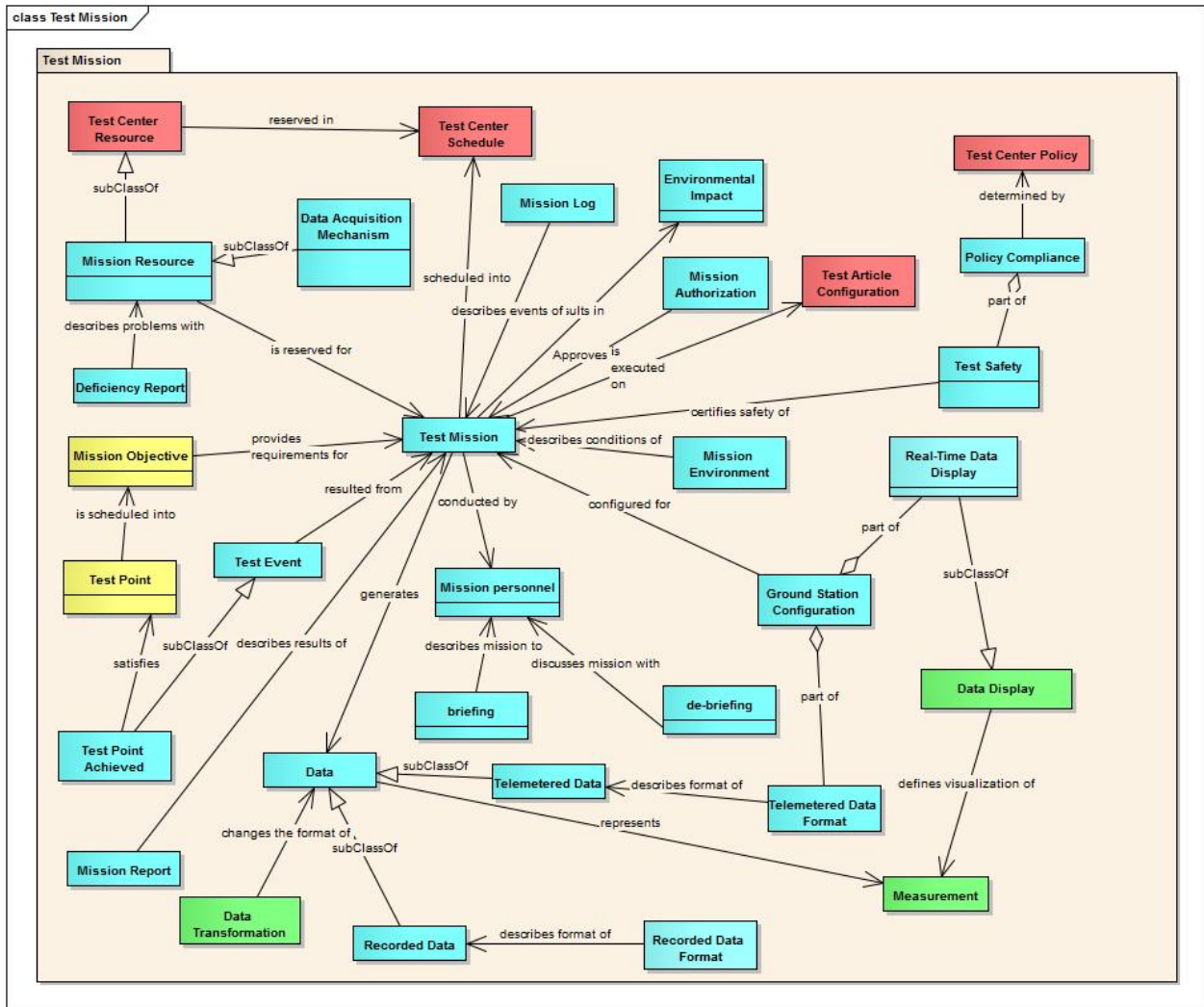
Figure 4-4.   Test Mission Portion of the T&E Ref Mod.

The Test Mission section of the T&E Ref Mod is composed of the following elements:

TABLE 4-3. ELEMENTS OF THE TEST MISSION SECTION OF THE T&E REF MOD	
Element Name	**Definition**
Briefing	Pre test meeting to describe testing to be performed
Data	information gathered during the test mission
Data Acquisition Mechanism	Equipment used to collect data (e.g. instrumentation, radar, notepad, etc)
De-briefing	post test meeting to discuss testing that has been performed
Deficiency Report	describes problems with any mission resources
Environmental Impact	Describes impact the mission had on the environment, if any
Ground Station Configuration	Real-time data display and Command and Control (C2) systems used during test, real-time data format descriptions, software and versions, etc.
Mission Authorization	Describes authorization of a mission by an authority
Mission Environment	Weather/other conditions during test, course conditions, etc.
Mission Log	Description of events that took place during a mission
Mission Personnel	People assigned to a test
Mission Report	Information gathered during the test mission, "results" of the mission.
Mission Resource	Any test center resource that is used for this mission
Policy Compliance	Documents whether the mission conformed to the Test Center Policies
Real-Time Data Display	Description of the display and configurations used to display real-time Information in the control room during test (hardware, software, configuration files, etc)
Recorded Data	data captured during test mission
Recorded Data Format	description of how captured data is formatted (e.g. Chapter 10)
Telemetered Data Format	Description of the format of real-time telemetered data (e.g. RCC Document 106, Chapter 9)
Telemetered Data	Real-time instrumented data
Test Event	Something of interest that occurs during a test (e.g. execution of a test point, unexpected events, etc.)
Test Mission	Common descriptor for physical performance of test
Test Points Achieved	Specific items listed as test points that have successfully been measured, and the details of that item as it was actually performed
Test Safety	Specific criteria implemented to insure safety

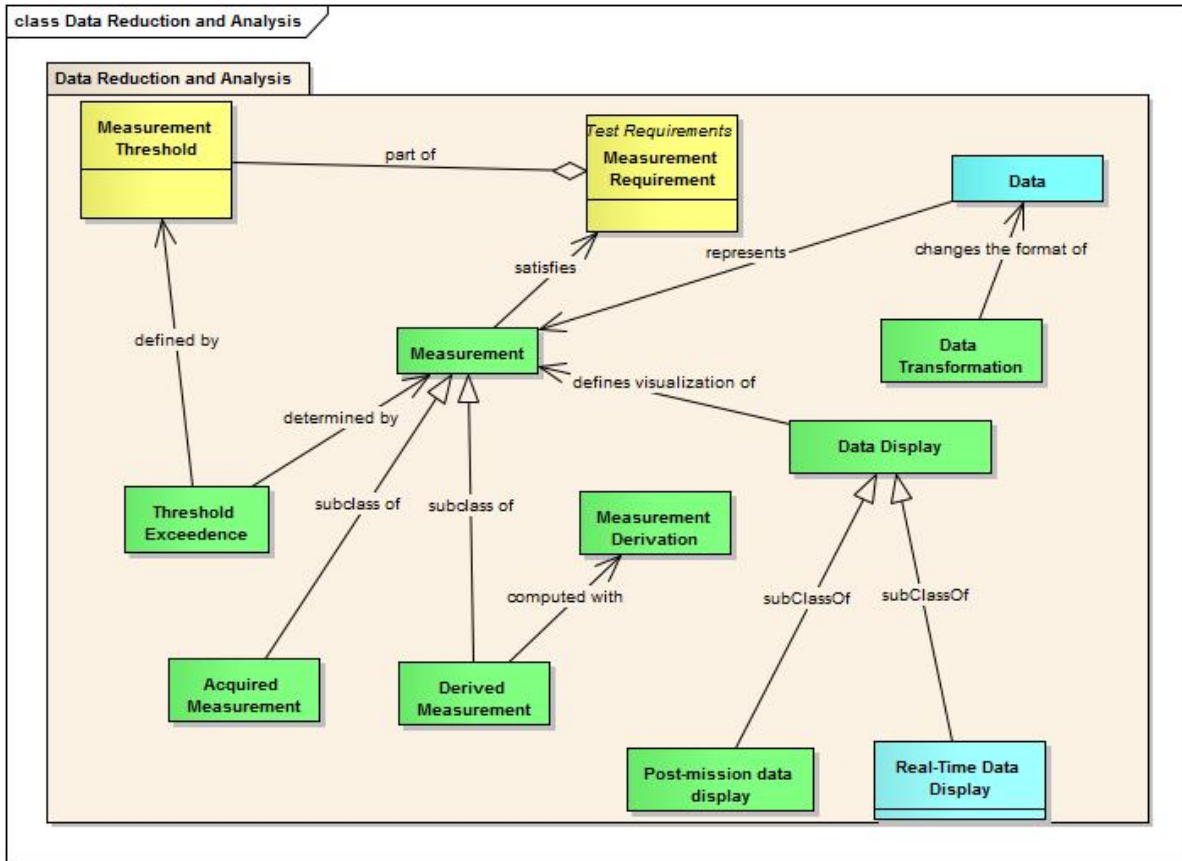## 4.4   Data Reduction and Analysis Sub-model

Figure 4-5.   Data Reduction and Analysis Portion of the T&E Ref Mod.

Elements of the Data Reduction and Analysis section of the T&E Ref Mod.

TABLE 4-4. ELEMENTS OF THE DATA REDUCTION AND ANALYSIS SECTION OF THE T&E REF MOD	
Element Name	**Definition**
Acquired Measurement	data gathered in support of test point
Data Display	systems used to view data, and specifications of the specific displays used
Data Transformation	changes made to data to make it usable
Derived Measurement	measurements after changes to account for specific conditions, or computed from other data
Measurement	information gathered during the test mission
Measurement Derivation	specific changes to be made to data to correct (or true) it, or compute it from other data
Post-mission Data Display	non real time display of data - visualization of recorded data
Threshold Exceedance	Description of the moment at which derived data values passed outside of the defined Measurement Thresholds

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CHAPTER 5

CONCLUSIONS

A T&E Metadata Reference Model has been created that provides documentation of the complete set of metadata types involved in the T&E process. This model is intended to serve as the common terminology for T&E metadata across ranges, regardless of the organization performing the test or the type of article being tested. Additionally, the model serves as a basis for developing standards-based metadata management software applications, and allows organizations to understand the global set of information that is relevant to any T&E metadata management system.

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