National Aeronautics and
Space Administration

SLS-PLAN-175

VERSION 1

RELEASE DATE: MARCH 25, 2013

SPACE LAUNCH SYSTEM PROGRAM (SLSP) INTEGRATED MEASUREMENT AND COMMAND SYSTEM (IMACS) DEVELOPMENT PLAN

REVISION AND HISTORY PAGE

Status	Version No.	Change No.	Description	Release Date
Released	1		Initial Release of SLS DRD 1406AS-033 for SLS PDR, MSFC 4511 Concurrence on file	03/25/2013

NOTE: Updates to this document, as released by numbered changes (Change XXX), are identified by a black bar on the right margin.

Contents

1.0 INTRODUCTION

The integration, test and operational activities for SLS require the capacity to route and transmit commands and measurements to various points both internal and external to the launch vehicle system. Provision of this capability necessitates a process of collecting, organizing, controlling and maintaining data and metadata regarding these signals and their associated information into a single-point source for use by the SLS community. This authoritative source of data, metadata, and associated information on the SLS Program is the Integrated Measurement and Command System (IMACS) database.

IMACS will include consolidated metadata with regard to the SLS vehicle, including command and measurement definitions, mapping of data and command signal paths across the vehicle and external commands and telemetry formats. The contents of this database will provide a means to trace a command from its source such as a Ground System Software external command all the way to the corresponding end effector. Other information to be contained within this database will describe launch commit criteria (LCC) and Caution and Warning (C&W) information as well as Health and Status. Also included for Development Flight Instrumentation (DFI) will be reference links to detailed test objectives (DTO) and flight test objectives (FTO) that relate to the sensors as supporting justification for the sensors.

The advantages to having consolidated data rather than a disparate collection of data include:

- Mitigates the risk of inconsistent data. The process of integrating the data helps uncover variances in data definition or allowed (i.e., valid) values that frequently are missed by manual comparison of data from multiple, disparate sources such as different Interface Control Documents.
- Provides a means to look at the "big picture" by permitting the capability to analyze the data across what would normally be organizational or project boundaries.
- Facilitates the ability to perform consistent validation of the consolidated values.
- The use of common column definitions between different database tables, will make it possible to add new data if required in the future to extend the analysis capabilities. For example, Ares experience showed that the IMACS database may be used to introduce new information such as the external to internal command mapping back to specific requirements.
- Use of a relational database permits analysis of the data from various perspectives, i.e., the ability to "slice and dice" the data in various ways not supported by the use of static media such as spreadsheets or other flat files.
- Use of a relational database offers a platform which can be augmented with tools to permit interactive query and reporting as well as web access, if required.

1.1 Purpose

The contents of the IMACS database constitute a consolidated source for SLS Program metadata regarding command and telemetry definitions. This SLS IMACS Development Plan captures the requirements for the IMACS software capabilities, the database content, control of the data, data access, and the format and scope of output products.

1.2 Scope

This Plan is applicable to all Elements of the SLS Program and activities in support of the SLS Program. The IMACS development activities and database content will be coordinated with the Ground Systems Development and Operations Program (GSDOP), the Multi-Purpose Crew Vehicle (MPCV) Program, and any other entities making use of SLS commands or telemetry.

1.3 Change Authority/Responsibility

The NASA MSFC Office of Primary Responsibility (OPR) for this document is The Space Systems Department Systems Engineering Branch, ES13.

Changes to this document will be controlled at the OPR level using processes defined by the OPR.

2.0 DOCUMENTS

2.1 Applicable Documents

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein.

NPR 7150.2A	NASA Software Engineering Requirements
MPR 7150.1	MSFC Software Engineering Requirements
SLS-PLAN-024	Space Launch Systems Program Software Management Plan
SLS-STD-172	Space Launch Systems Program Command and Telemetry Representation and Metadata Exchange Standards

2.2 Reference Documents

The following documents contain supplemental information to guide the user in the application of this document.

MSFC-STD-1924	Standard for Instrumentation Program and Command Lists (IP&CL)
SLS-PLAN-004	SLSP Data Management Plan
SLS-PLAN-020	Space Launch System (SLS) Program Concept of Operations (Con Ops) Document

3.0 SLS IMACS DESCRIPTION

3.1 Need Statement

There is a need for consolidated source of metadata for the SLS Program that describes commands, measurements, telemetry and bus message details as well as launch commit and safety/abort information relevant to a given launch vehicle to support SLS design, development, testing, integration, operations and post mission analysis.

3.2 Goal

The goal of the IMACS effort is to provide a single source of consolidated and validated flight vehicle avionics, housekeeping and safety/aborts information in a shared and controlled repository to support the SLS Program.

3.3 Objectives

The objective of this task is to make available a single, authoritative view of the vehicle's validated avionics and flight-related measurement and command metadata within the SLS Program for all stakeholders to share.

3.4 Mission

The mission of the IMACS is to provide a common repository of validated metadata for the SLS Program that describes SLS commands, measurements, telemetry, bus messages, sensor and effector details, as well as related launch commit criteria and safety/abort criteria.

3.5 Software Classification

A preliminary classification assessment of the IMACS software indicates that it is Class C software.
A preliminary assessment of safety criticality indicates it is safety critical software.

3.6 Operational Concept Summary

Figure 3.6.1 illustrates the operational concept for the IMACS. SLS vehicle command and telemetry metadata is collected from avionics hardware suppliers by SLS Program Stages Element and integrated into the Boeing Instrumentation Program and Command List (IP&CL). Stages will also collect metadata on the Booster and Engine command and telemetry metadata crossing the interfaces with the Core Stage and integrate that data into the Boeing IP&CL. The Boeing IP&CL will be provided to the IMACS team as an input to the Level 2 IMACS database. The IMACS team will gather data from SLS Flight Software (FSW) and the Systems Integration Laboratory (SIL). The IMACS Team will also gather data from the external systems interfacing with SLS (MPCV, GSDO, Mission Systems (MS), SLS Engineering Support Center (SESC), etc.) from ICDs and other sources. The metadata provided by the disparate sources will be validated and integrated into the IMACS database and reports will be provided back to the suppliers for verification that their inputs have been correctly loaded.

Reports will also be provided for use by the stakeholders of the IMACS metadata, including GSDO, SIL, MS, SESC, and Flight Software.

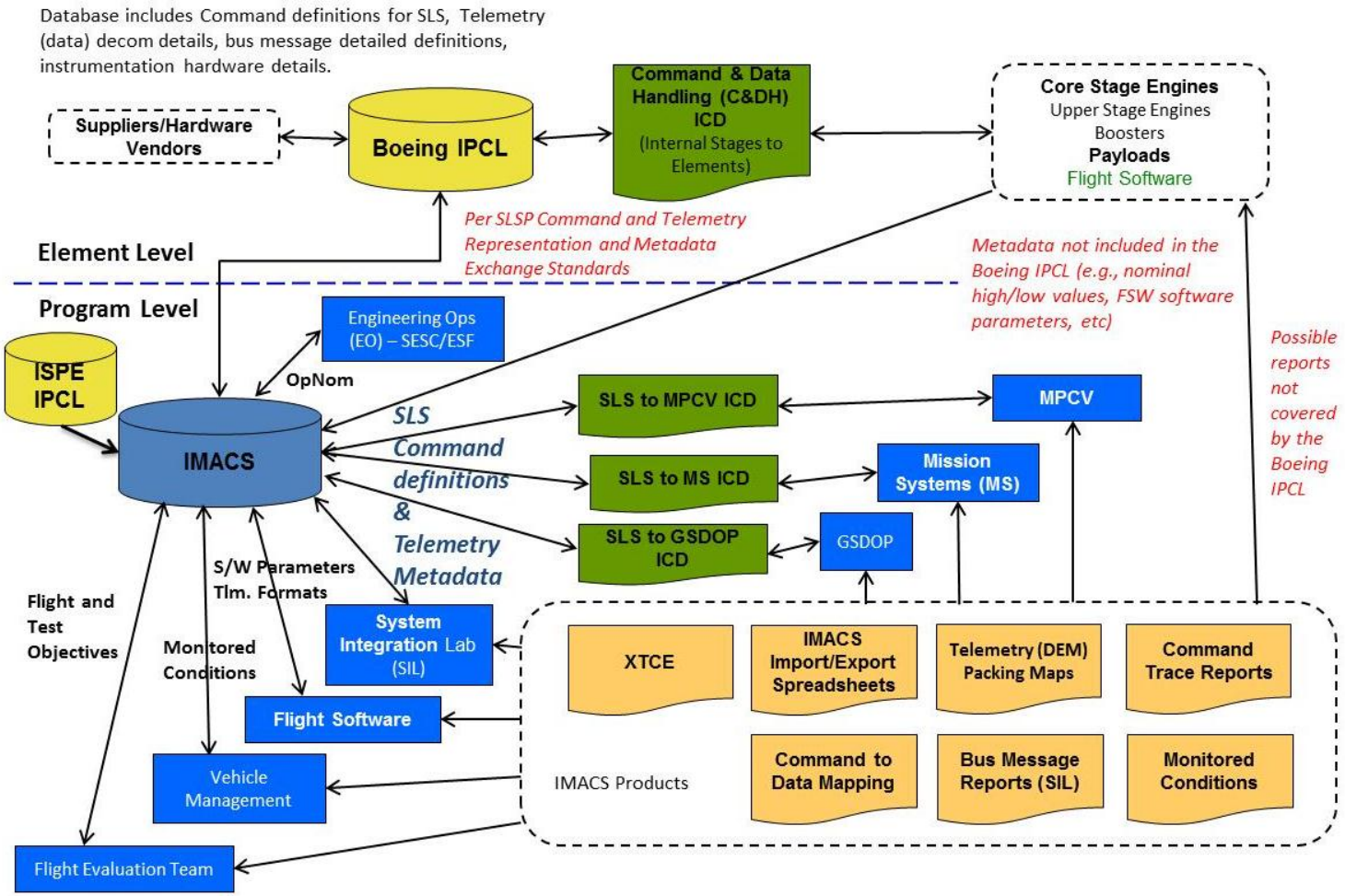

Figure 3.6-1 IMACS Data Flow

Appendix C presents a series of figures that describe the activities performed by the IMACS team in developing and operating the Integrated Measurement and Command System to document and deliver the IMACS products required by the IMACS stakeholders.

The following paragraphs summarize the anticipated development, use and maintenance of the IMACS during SLS development and operations:

3.6.1 SRR/SDR to PDR

- Prepare and deliver the Space Launch Systems (SLS) Integrated Measurement and Command System (IMACS) Plan (this document) and the Space Launch Systems Program Command and Telemetry Representation and Metadata Exchange Standards for configuration control.
- Develop database schema to facilitate metadata entry, storage and access.
- Develop processes for data repository maintenance and control.
- Collect and load repository metadata from the SLS Stages IP&CL, interface control document definitions, SIL, S&MA, GSDO, and payloads including MPCV.
- Provide the stakeholder community with reports generated from the SLS System IMACS data repository content.
- Evaluate stakeholder comments and requested changes, accept those meeting repository criteria, and revise IMACS documentation as necessary.
- Track changes to the data repository and provide traces to supporting change documentation.
- Maintain repository data security.

3.6.2 PDR to CDR

- Review software classification, and safety criticality assessments per MPR 7150.1 .
- Complete MPR 7150.1 compliance matrix.
- Process changes to this document and the Space Launch Systems Program Command and Telemetry Representation and Metadata Exchange Standards as necessary to meet stakeholder requirements.
- Continue development of database schema as necessary to meet revisions to controlling documents.
- Establish ES13 OPR access control of the repository.
- Establish the repository as the authoritative source of SLS System command and telemetry metadata.
- Provide the stakeholder community with reports generated from the data repository content.
- Accept, validate, and load authorized metadata additions and changes..

3.6.2 PDR to CDR (continued)

- Track changes to the data repository and maintain traces to supporting change documentation.
- Maintain repository data security.

3.6.3 CDR to DCR

- Establish SLS access control of the repository.
- Maintain the repository as the authoritative source of SLS System command and telemetry metadata.
- Accept, validate, and load authorized metadata additions and changes.
- Provide the stakeholder community with reports generated from the data repository content.
- Track changes to the data repository and maintain traces to supporting change documentation.
- Maintain repository data security.

3.6.4 Operational Phase

- Maintain the repository as the authoritative source of SLS Level 2 command and telemetry metadata.
- Accept, validate, and load authorized metadata updates for all data sets.
- Provide the stakeholder community with reports generated from the data repository content.
- Track changes to the data repository and maintain traces to supporting change documentation.
- Maintain repository data security

3.7 SLS IMACS Requirements

The requirements in this section document the database design features considered to be necessary to provide a fully functional consolidated source of metadata for the SLS Program.

3.7.1 IMACS Metadata Processing Requirements

[IM1001] IMACS Implementation

The IMACS metadata repository shall be implemented on a relational database management system.

A relational database allows data to be rapidly accessed or reassembled in many different ways without having to reorganize the database tables. Use of relational database management is standard practice in business and industry.

[IM1002] IMACS Metadata Acceptance

IMACS shall accept metadata that adhere to the standards and conventions specified in the SLSP Command and Telemetry Representation & Metadata Exchange Standards document.

Rationale: The rationale for use of the standard is to provide a consistent input format to the IMACS metadata repository.

Reference: SLS-STD-172, SLSP Command and Telemetry Representation & Metadata Exchange Standards

[IM1003] Supported Data Types

IMACS shall support the data types specified in the SLSP Command and Telemetry Representation & Metadata Exchange Standards document.

To allow successful metadata integration, the content of the repository is restricted to the specified standard data types.

Reference: SLS-STD-172, SLSP Command and Telemetry Representation & Metadata Exchange Standards

[IM1004] Engineering Units Supported

IMACS shall support the engineering units specified in the SLSP Command and Telemetry Representation & Metadata Exchange Standards.

To allow successful metadata integration, the content of the repository is restricted to the specified standard engineering units.

Reference: SLS-STD-172, SLSP Command and Telemetry Representation & Metadata Exchange Standards

[IM1005] IMACS Metadata Integration

IMACS shall integrate validated metadata that have been provided from different sources.

*This is a statement of the IMACS function. Metadata will be validated for adherence to the SLSP Command and Telemetry Representation & Metadata Exchange Standards document in accordance with **[IM1002]**.*

Reference: SLS-STD-172, SLSP Command and Telemetry Representation & Metadata Exchange Standards

[IM1006] Identification of Data Owner

IMACS shall identify the entity with the authority to authorize changes to a specific metadata record.

Identification of the metadata record owner is necessary to insure valid metadata. Ownership entities can include documents (i.e, ICDs), specific organizational departments, or individuals. Changes will only be accepted from the identified entity.

[IM1007] Maintenance of Datasets

IMACS shall provide the capability to maintain distinct collections of metadata definitions called datasets.

Distinct datasets will be required to maintain metadata for distinct missions, versions, and SIL and GSDO tests.

[IM1008] Dataset Accessibility

IMACS shall provide the capability to maintain up to 10 datasets in the IMACS data repository at any given time.

This capability allows for different datasets to be in simultaneous use in support of various stakeholders, i.e. several SIL configurations and several SLS missions

[IM1009] Dataset Creation

IMACS shall allow the creation of a new dataset or datasets.

This capability allows for creation of datasets representing new test configurations, revised designs, or new missions.

[IM1010] Metadata Transfer

IMACS shall allow metadata from an existing specified dataset to be copied to a new specified dataset.

This capability avoids the need to reenter existing data.

[IM1011] Dataset Deletion

IMACS shall allow the deletion of a specified dataset.

This capability allows the removal of obsolete or invalid datasets from the data base.

[IM1012] Dataset Archival

IMACS shall provide the capability to archive datasets and maintain them in archive for the life of the program.

This capability avoids the permanent loss of a dataset.

[IM1013] Restoration of Archived Datasets

IMACS shall allow restoration of a specific archived dataset to the IMACS metadata repository so that it is available for online access.

This capability is needed to restore accessibility to a given dataset.

[IM1014] Data Extraction

IMACS shall allow extraction of associated data from the IMACS metadata repository using filtering techniques based on one or more attribute values.

This capability is required to create reports based on user requirements.

[IM1015] Repository Backup

IMACS shall allow backup of the entire contents of the IMACS metadata repository.

This capability supports restoration of the entire contents of a database and provides for disaster recovery.

[IM1016] Backup of Selected Datasets

IMACS shall allow backup of a selected dataset from the IMACS metadata repository.

This capability supports restoration of the contents of a database in the event of database corruption or loss of contents.

[IM1017] Attribute Value Modification

IMACS shall allow modification of one or more attribute values in a dataset according to rules and permissions defined in the IMACS metadata repository.

The rationale is ***<TBD-001>***

[IM1018] Insertion of Validated Metadata

IMACS shall allow insertion of new metadata records based on explicit validation rules specified in the IMACS metadata repository.

This capability provides a means to add new validated records as metadata definition matures.

[IM1019] Deletion of Metadata

IMACS shall allow deletion of one or more metadata records from a specific dataset based on rules specified in the IMACS metadata repository.

This capability provides a means to remove records that become obsolete as metadata definition matures.

[IM1020] Change History

IMACS shall provide the capability to maintain, for the life of the program, a history of changes associated with a given metadata record identified by a given primary key.

This capability provides change records that allow complete reconstruction of change history, including reason for change and change authorization.

[IM1021] Maintenance of Attribute Values

IMACS shall maintain independent values for one or more specified attributes associated with a common unique identifier across different datasets.

Different datasets will sometimes need to recapture different values of a measurement or command due to changing levels of maturity of the metadata.

[IM1022] Assignment of Primitive Signal Definition IDs

IMACS shall assign unique identification for each new primitive signal for which metadata are collected.

The rationale is <TBD-001>

[IM1023] Common Primitive Signal CUIs Across Datasets

IMACS shall maintain a common unique identifier (CUI) for a given primitive signal across different datasets.

The rationale is <TBD-001>

SLS-type-nnnn, Title

[IM1024] Unique Identification for Commands

IMACS shall assign unique identification for each new command for which metadata are collected.

The rationale is <TBD-001>

[IM1025] Command CUI

IMACS shall maintain a common compact unique identifier (CUI) for a given command across multiple datasets.

The rationale is <TBD-001>

[IM1026] Unique Identification for Groups

IMACS shall assign unique identification for each new group definition for which metadata are collected.

The rationale is <TBD-001>

SLS-type-nnnn, Title

[IM1027] Association of Mission Phase with Command

IMACS shall permit association of one or more valid mission phases with a given command.

This capability supports checking the validity of a command during a specific mission phase.

[IM1028] Command Receipt Verification

IMACS shall permit association of one or more measurement values with a given command for the purpose of verifying that the command has been received.

This capability allows checking the values for one or more measurements to determine if the receipt of the command was successful.

[IM1029] Command Acceptance Verification

IMACS shall permit association of one or more measurement values with a given command for the purpose of verifying that the command has been accepted.

The rationale is <TBD-001>

[IM1030] Command/FSW SRS Association

IMACS shall provide the capability to identify a flight Software Requirements Specification requirement associated with a given command.

The rationale is <TBD-001>

[IM1031] Command Valid FSW Modes

IMACS shall provide the capability to identify the valid flight software modes for a given command.

The rationale is <TBD-001>

[IM1032] Hazardous Command Identification

IMACS shall provide the capability to identify (flag) hazardous commands.

The rationale is <TBD-001>

SLS-type-nnnn, Title

[IM1033] Store Static Alarm Limits

IMACS shall provide the capability to store static alarm limits for a given measurement.

The rationale is <TBD-001>

SLS-type-nnnn, Title

[IM1034] Store Enumerated Alarm Limits

IMACS shall provide the capability to store enumerated alarm limits for a given measurement.

The rationale is <TBD-001>

SLS-type-nnnn, Title

[IM1035] Store Change Alarms

IMACS shall provide the capability to store change alarms for a given measurement.

The rationale is <TBD-001>

SLS-type-nnnn, Title for a given measurement

[IM1036] Identify Test Objectives

IMACS shall provide the capability to identify (flag) the development test objectives (DTOs) and flight test objectives (FTOs) satisfied by a given measurement.

This capability permits correlation of one or more measurements with the requirement for its existence. Conversely, it permits identification of a specific test objective that would be affected by loss of the measurement.

[IM1037] Store Measurement Criticality Ratings

IMACS shall provide the capability to store criticality ratings for a given measurement.

The rationale is <TBD-001>

SLS-type-nnnn, Title

[IM1038] Store Measurement Data Rates

IMACS shall provide the capability to store the data rates of individual measurements within a message.

This capability is needed to group measurements for assignment to a given DEM and/or telemetry format.

[IM1039] Association of Mission Phase with Measurement

IMACS shall provide the capability to associate one or more valid mission phases with a given measurement. **<TBR-001>**

This capability is required to associate a given measurement with the telemetry format to be utilized during a specific mission phase.

[IM1040] Message Start Time Capture

IMACS shall capture the message start time for each MIL-STD-1553B bus message.

This metadata is needed by FSW to correctly populate the MIL-STD-1553B bus minor frames.

[IM1041] Line Segment Calibration Representation

IMACS shall provide the capability to represent line segment calibration data in the point pair format in output products.

*The rationale is **<TBD-001>***

SLS-type-nnnn, Title

[IM1042] Calibration Data per Mission Phase

IMACS shall provide the capability to different measurement calibration data based on mission phase. **<TBR-001>**

This capability allows for the use of unique measurement calibrations during different mission phases.

[IM1043] Unique Identification for Sensors

IMACS shall provide the capability assign unique identification for each new sensor for which metadata are collected.

*The rationale is <**TBD-001**>*

SLS-type-nnnn, Title

[IM1044] Association of Drawing with Sensor

IMACS shall provide the capability to associate a drawing number with a given sensor.

*The rationale is <**TBD-001**>*

SLS-type-nnnn, Title

[IM1045] Association of Reference Designator with Sensor

IMACS shall permit association of a reference designator with a given sensor.

*The rationale is <**TBD-001**>*

SLS-type-nnnn, Title

[IM1046] Association of Location with Sensor

IMACS shall permit association of a location with a given sensor.

*The rationale is <**TBD-001**>*

SLS-type-nnnn, Title

[IM1047] Unique Identification for Effectors

IMACS shall assign unique identification for each new effector for which metadata are collected.

*The rationale is <**TBD-001**>*

SLS-type-nnnn, Title

[IM1048] Association of Mission Phase with Telemetry Format

IMACS shall provide the capability to identify applicable mission phases for each telemetry format. <**TBR-001**>

*The rationale is <**TBD-001**>*

SLS-type-nnnn, Title

[IM1049] DEM Data Transfer Rate

IMACS shall store the data transfer rate for a given telemetry data exchange message (DEM).

The rationale is <TBD-001>

Reference: SLS-type-nnnn, Title

[IM1050] Telemetry Link Maximum Data Transfer Rate

IMACS shall store the maximum data transfer rate for a given telemetry link.

The rationale is <TBD-001>

Reference: SLS-type-nnnn, Title

[IM1051] Bus Maximum Data Transfer Rate

IMACS shall store maximum data transfer rates for a given bus.

The rationale is <TBD-001>

Reference: SLS-type-nnnn, Title

[IM1052] Association of Effectivity with Data Sets

IMACS shall provide the capability to assign an effectivity to each data set.

Each IMACS data set represents a single flight or test. This complements requirement [IM2004].

Reference: SLS-type-nnnn, Title

[IM1053] Map Ground System Commands

IMACS shall provide the capability to map a Ground System command through the Flight Computer to a subsystem/assembly/effector.

This capability is needed for integration testing.

[IM1054] Data Import Format

IMACS shall import data that conforms to the import formats identified in the SLSP Command and Telemetry Representation & Metadata Exchange Standards document.

Rationale: To allow successful metadata integration, the content of the repository is restricted to the specified standards.

Reference: SLS-STD-172, SLSP Command and Telemetry Representation & Metadata Exchange Standards

[IM1055] Association of Identification Data with a Sensor

IMACS shall allow association of a serial number, lot/batch number, or date code with a sensor.

Rationale: Some sensors may require individual or lot calibration.

[IM1056] Association of a Sensor with a Measurement

IMACS shall provide the capability to identify the hardware sensor with which a measurement is associated, if any.

Rationale: The rationale is: <TBD-001>

3.7.2 IMACS Report Creation

[IM2001] Human Readable Report Creation

IMACS shall create human readable reports as defined in the SLSP Command and Telemetry Representation & Metadata Exchange Standards document.

Human readable reports are required by IMACS metadata users. The report format will also be used by the users to supply additional and/or updated data.

Reference: SLS-STD-172, SLSP Command and Telemetry Representation & Metadata Exchange Standards

[IM2002] Machine Readable Report Creation

IMACS shall create machine readable products as defined in the SLSP Command and Telemetry Representation & Metadata Exchange Standards document.

Machine readable products are required by IMACS metadata users for ingestion into their databases and/or systems.

Reference: SLS-STD-172, SLSP Command and Telemetry Representation & Metadata Exchange Standards

[IM2003] Comparison Report Creation

IMACS shall allow creation of a comparison report that identifies differences between two distinct datasets.

Such a comparison report is required to document the changes from one version of a dataset to another and to provide insight of such changes to stakeholders.

[IM2004] Change History Report Creation

IMACS shall provide reports documenting the change history of one or more specific items in the metadata repository.

The rationale is <TBD-001>

Reference: SLS-type-nnnn, Title

3.7.3 IMACS Metadata Access Requirements

[IM3001] User Authentication

IMACS shall provide two-part authentication of users as required by NPR 2810.1A.

Two- part authentication is required by Homeland Security Presidential Directive 12 (HSPD-12). This directive is flowed down to NASA through NPR 2810.1A.

[IM3002] User Authorization Credentials

IMACS shall use user authorization credentials common to multiple NASA locations.

The rationale is <TBD-001>

SLS-type-nnnn, Title

[IM3003] IMACS Read Access

IMACS shall provide read access to metadata within the repository by authorized users.

Read access has been requested by the SIL, SESC, and GSDO.

[IM3004] IMACS Data Accessibility

IMACS metadata shall be accessible from remote locations under controlled read only access.

***Rationale**: Authorized users including the SIL, SESC, and GSDO will be remote users.*

[IM3005] IMACS Write Access

IMACS shall provide selective write access to metadata within the repository by authorized users.

Write access is required by authorized users to load inputs provided by data suppliers.

3.8 Assumptions Regarding IMACS Requirements

3.8.1 Input Data Processing

- Data will be provided to the IMACS using a consistent format as specified in the SLSP Command and Telemetry Representation & Metadata Exchange Standards document.
- Validation of data content that is submitted to IMACS will be based on valid values and naming conventions as specified in the SLSP Command and Telemetry Representation and Metadata Exchange Standards document.
- Metadata submissions that will not validate will be returned to the source/provider for correction and re-submission.
- Nomenclature used for data submissions will be consistent (e.g., start word, message, packet definitions, etc.) across all stakeholders based on the SLSP Command and Telemetry Representation and Metadata Exchange Standards document.
- No change history of a given IMACS value will be maintained for data within a single working dataset – the value of any parameter will be valid for that point in time only. For example, if a calibration parameter is provided on Wednesday and the input is revised on Thursday, only the current value at that time is represented in IMACS.
- If both SIL and FSW decide to define a measurement or command, it is possible that they will be treated as two different entities and assigned two different identifiers. The change management process will have to cover this case.

3.8.2 Other Assumptions

- The assumption is made that IMACS will continue to use the current GFE computer systems.
- The assumption is made that FY13 staffing will be adequate to meet IMACS development and implementation schedules.
- The assumption is made that computer equipment and software licenses will continue to be provided by the ACES and MITS contracts.

3.8.3 Authority and Responsibility

- Database administration is provided by MITS personnel.
- The IMACS team performs database schema definition, data preparation, validation and loading into the database
- The IMACS database houses metadata that are considered to be the authoritative source of Level 2 SLS Avionics Metadata.

4.0 VERIFICATION PROVISIONS

4.1 General

This section identifies activities required to verify that the requirements of Section 3 have been satisfied. Verification approach for the SLS Program is provided in the SLS Verification and Validation (V&V) Plan.

4.2 Verification methods

The IMACS repository design shall be verified by analysis, demonstration, inspection, test, and/or validation of records or similarity (or a combination thereof) as specified herein to assure compliance with Section 3. Definitions of verification methods are from Marshall Work Instruction (MWI) 8050.1, Verification & Validation of Hardware, Software, and Ground Support Equipment for MSFC Projects.

4.2.1 Analysis

Analysis involves the use of engineering analysis, qualitative assessment, computer modeling, and/or simulations to ensure compliance to the requirement(s). Analysis is a method used in lieu of, or in addition to, testing.

4.2.2 Inspection

Inspection is the physical evaluation to ensure that the requirement(s) has been incorporated or met. Inspection shall be used as the method on the product to satisfy such requirements as construction features, workmanship, dimensions, and physical conditions identified on the engineering documentation (e.g., drawings, Engineering Parts List).

4.2.3 Demonstration

Demonstration is the "acting out" to ensure the requirement(s) has been incorporated or met. Demonstration shall be used as the method on the product to satisfy such requirements as accessibility, replace-ability, and human factors.

4.2.4 Test

Test (e.g., functional, environmental) is the actual operation to ensure that the performance is in accordance with the requirement(s).

4.2.5 Validation of Records

Validation of records is the use of vendor-furnished/supplied manufacturing or processing records to ensure the requirement(s) has been incorporated or met. Validation of records shall be used as the method to satisfy incorporation of requirements for such items as commercial off-the-shelf (COTS) products and products purchased to standards.

4.3 Verification Matrix

4.3.1 SLS Verification Matrix <TBD-002>

The verification methods for the IMACS with accompanying rationale are shown in Table 4-1.

Table 4-1, IMACS Verification Methods

Reqmt.		Verif. Method					
Number	Title	A	I	D	T	V R	Verification Comments
IM1001	IMACS Implementation						
IM1002	IMACS Metadata Acceptance						
IM1003	Supported Data Types						
IM1004	Engineering Units Supported						
IM1005	IMACS Metadata Integration						
IM1006	Identification of Data Owner						
IM1007	Maintenance of Datasets						
IM1008	Dataset Accessibility						
IM1009	Dataset Creation						
IM1010	Metadata Transfer						
IM1011	Dataset Deletion						
IM1012	Dataset Archival						
IM1013	Restoration of Archived Datasets						
IM1014	Data Extraction						
IM1015	Repository Backup						
IM1016	Backup of Selected Datasets						
IM1017	Attribute Value Modification						
IM1018	Insertion of Validated Metadata						
IM1019	Deletion of Metadata						
IM1020	Change History						
IM1021	Maintenance of Attribute Values						
IM1022	Assignment of Primitive Signal Definition IDs						
IM1023	Common Primitive Signal CUIs Across Datasets						

Reqmt.		Verif. Method					
Number	Title	A	I	D	T	V R	Verification Comments
IM1024	Unique Identification for Commands						
IM1025	Command CUI						
IM1026	Unique Identification for Groups						
IM1027	Association of Mission Phases with Command						
IM1028	Command Receipt Verification						
IM1029	Command Acceptance Verification						
IM1030	Command/FSW SRS Association						
IM1031	Command Valid FSW Modes						
IM1032	Hazardous Command Identification						
IM1033	Store Static Alarm Limits						
IM1034	Store Enumerated Alarm Limits						
IM1035	Store Change Alarms						
IM1036	Identify Test Objectives						
IM1037	Store Measurement Criticality Ratings						
IM1038	Store Measurement Data Rates						
IM1039	Association of Mission Phase with Measurement						
IM1040	Message Start Time Capture						
IM1041	Line Segment Calibration Representation						
IM1042	Calibration Data per Mission Phase						
IM1043	Unique Identification for Sensors						
IM1044	Association of Drawing with Sensor						
IM1045	Association of Reference Designator with Sensor						

Reqmt.		Verif. Method					
Number	Title	A	I	D	T	V R	Verification Comments
IM1046	Association of Location with Sensor						
IM1047	Unique Identification for Effectors						
IM1048	Association of Mission Phase with Telemetry Format						
IM1049	DEM Data Transfer Rate						
IM1050	Telemetry Link Maximum Data Transfer Rate						
IM1051	Bus Maximum Data Transfer Rate						
IM1052	Association of Effectivity with Data Sets						
IM1053	Map Ground System Commands						
IM1054	Data Import Format						
IM1055	Association of Identification Data with a Sensor						
IM1056	Association of a Sensor with a Measurement						
IM2001	Human Readable Report Creation						
IM2002	Machine Readable Report Creation						
IM2003	Comparison Report Creation						
IM2004	Change History Report Creation						
IM3001	User Authentication						
IM3002	User Authorization Credentials						
IM3003	IMACS Read Access						
IM3004	IMACS Data Accessibility						
IM3005	IMACS Write Access						

5.0 METADATA CONFIGURATION MANAGEMENT

Figure 5.0 – 1 provides an overall view of the control and approval process envisioned for the IMACS database. Data provided by stakeholders (elements and users) is validated for adherence to the SLSP Command and Telemetry Representation and Metadata Exchange Standards document and loaded to an interim dataset. A comparison is made to the existing production dataset (which is under change control) and a change description report generated. This report is provided to the appropriate change approval board. (Note that the assumption is that this Board will change at CDR.) Personnel supporting the change approval board then generate a change request package based on the change description report. If approved by the appropriate board per their change approval process, the board will notify stakeholders and the IMACS team will be directed to update production database that will be disseminated to stakeholders. This cycle is repeated on a periodic basis until the dataset is fully completed and validated.

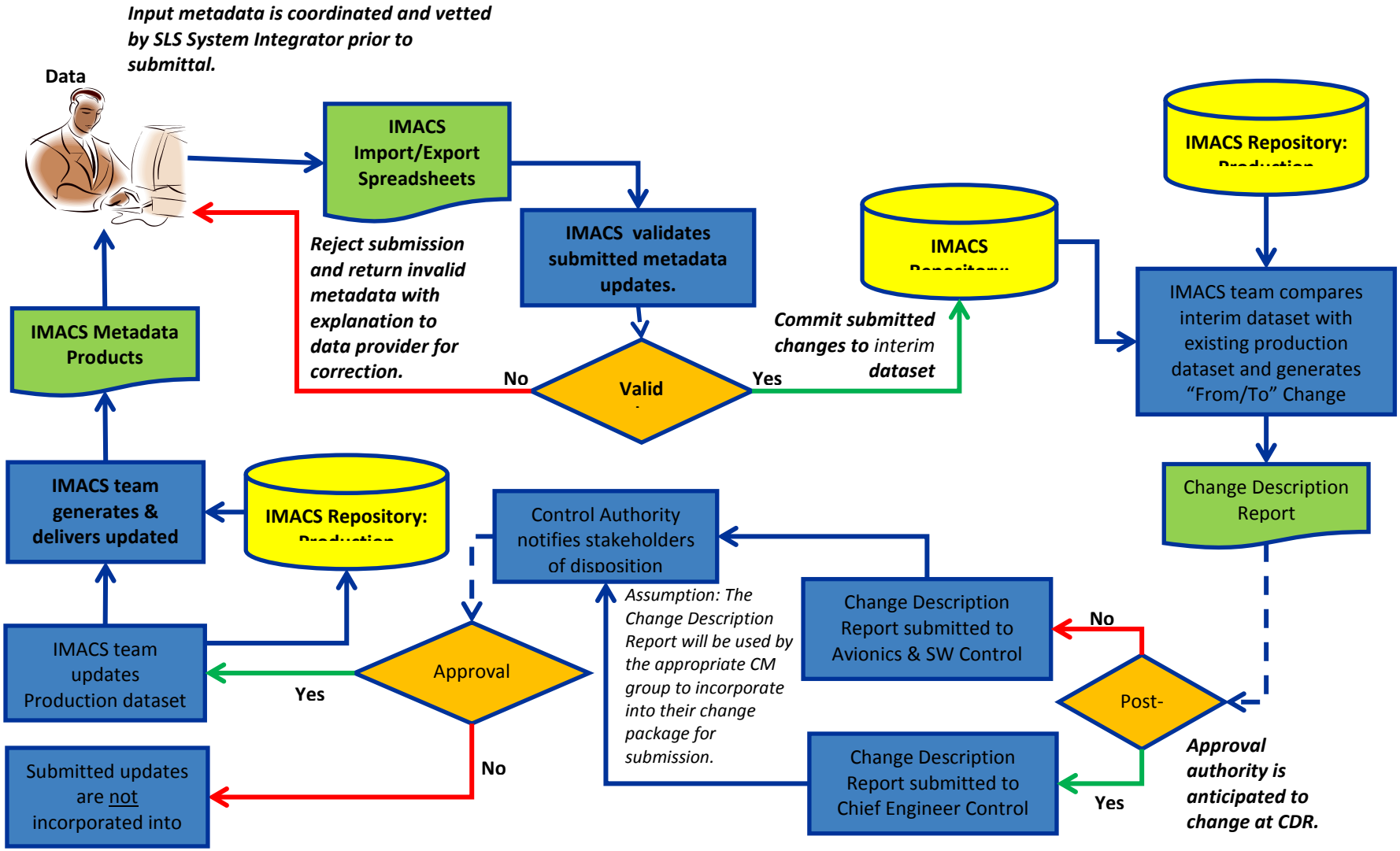

Figure 5.0-1 IMACS Metadata Control and Approval

APPENDIX A
ACRONYMS AND ABBREVIATIONS

ACES	Agency Consolidated End-User Services
C&W	Caution and Warning
CDR	Critical Design Review
CM	Configuration Management
COTS	Commercial Off The Shelf
CTN	Communication Tracking Network
CUI	Compact Unique Identifier
DCR	Design Certification Review
DEM	Data Exchange Message
DFI	Developmental Flight Instrumentation
DTO	Detailed Test Objectives
EPS	Electrical Power System
ES13	Systems Engineering Branch (organization code)
FC	Flight Computer
FDDR	Failure Detection, Diagnosis and Response
FDIR	Fault Detection Isolation and Recovery/Reconfiguration
FSW	Flight Software
FTO	Flight Test Objectives
GN&C	Guidance, Navigation & Control
GS	Ground Systems
GSDO	Ground Systems Development and Operations
GTI	Ground Test Instrumentation
HW	Hardware
ICD	Interface Control Document
IMACS	Integrated Measurement and Command System
I/O	Input/Output
IP&CL	Instrumentation Program & Command List
JSC	Johnson Space Center
KSC	Kennedy Space Center
LCC	Launch Commit Criteria
LS	Loss of Signal
LSB	Least Significant Bit
Mbps	Megabits per Second
MIS	Motion Imagery System
MITS	MSFC Information Technology Services

MO	Mission Operations
MPCV	Multi-Purpose Crew Vehicle
MS	Mission Systems
MSB	Most Significant Bit
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
OFI	Operational Flight Instrument
OPR	Office of Primary Responsibility
S&MA	Safety and Mission Assurance
SBU	Sensitive But Unclassified
SE&I	Systems Engineering and Integration
SESC	SLS Engineering Support Center
SIL	System Integration Laboratory
SMP	Software Management Plan
SW	Software
TBD	To Be Determined
TBR	To Be Resolved
VI	Vehicle Integration
WBS	Work Breakdown Structure
XTCE	XML (eXtensible Markup Language) Telemetric and Command Exchange

APPENDIX B
GLOSSARY OF TERMS

Term	Description
Flight	The sequence of events that takes place between liftoff and landing of a transportation vehicle.
Flight Software	The firmware and software required to manage the vehicle through all phases of ground processing and flight.
Bit Order	Identifies the order of the bits within a byte of memory. The two bit orders are Big Endian and Little Endian. Big Endian bit order. Big Endian bit order indicates that the most significant bit is placed in the byte first, and the remaining bits follow in decreasing order of significance so that the last significant bit occurs last. Little Endian bit order indicates that the least significant bit is placed in the byte first, and the remaining bits follow in increasing order of significance so that the most significant bit occurs last.
Byte Order	Identifies the byte order within a word of memory. The two bit orders are MSB and LSB. MSB Byte order indicates that the most significant byte is placed in the word first, and the remaining bytes follow in decreasing order of significance so that the last significant byte occurs last. LSB byte order indicates that the least significant byte is placed in the word first, and the remaining bytes follow in increasing order of significance so that the most significant byte occurs last.
Command	A directive to another element specified in terms of an action. The action can have one or more associated arguments, which are referenced within IMACS as parameters. If successful, the action will affect the state of an element (See definition of "element" below.)
Command Mapping	Relates one source command to one or more "target" (i.e., subsequent) commands that will be issued as a result of the source command. Not necessarily limited to GS SW to FC or MPCV to FC relationships.
Command Sequence	A grouping of commands used to automate the sequential execution of the commands. The definition of a sequence does not preclude multiple occurrences of the same command within a single sequence, nor does it imply whether the commands of a sequence are transmitted as individual commands or as a single block/packet containing multiple commands. For commands that have associated arguments, the command sequence definition will include the argument values for each specific occurrence of a command within the sequence.

Element	Physical entity that has functional capabilities allocated to them necessary to satisfy system-level mission objectives within the vehicle architecture. Elements can perform all system functions within a mission phase or through mated operations with other elements.
Effector	An actuator or other entity that has the ability to be commanded. An effector is attached to a hardware element and changes the state of the element in response to commands.
External Command	A command transmitted from Ground Support (GS) or MPCV to an element.
Ground Support Equipment (GSE)	Non-flight systems, equipment or devices necessary to support such operations as transporting, receiving, handling, assembly, inspection, test, checkout, servicing, launch and recovery of space systems, including spacecraft, launch vehicles and payloads at launch, landing or retrieval sites.
Internal Command	A command transmitted from the Flight Computer (FC) or Command and Telemetry Computer (CTC) to another component of the SLS vehicle avionics.
Word Order	Indicates the order of the words of memory within a group as they are transmitted across a bus or data link. The two word orders are MSW ands LSW. MSW word order indicates that the most significant word comes first in the group, and the remaining words follow in decreasing order of significance so that the least significant work occurs last. LSW word order indicates that the least significant word comes first in the group, and the remaining words follow in increasing order of significance so that he most significant word occurs last.

APPENDIX C
IMACS ACTIVITIES

This appendix presents a series of figures that describe the activities performed by the IMACS team in developing and using the Integrated Measurement and Command System to document and deliver the IMACS products required by the IMACS stakeholders. Active and continuing coordination is required to develop and deliver products that meet the evolving needs of the stakeholders.

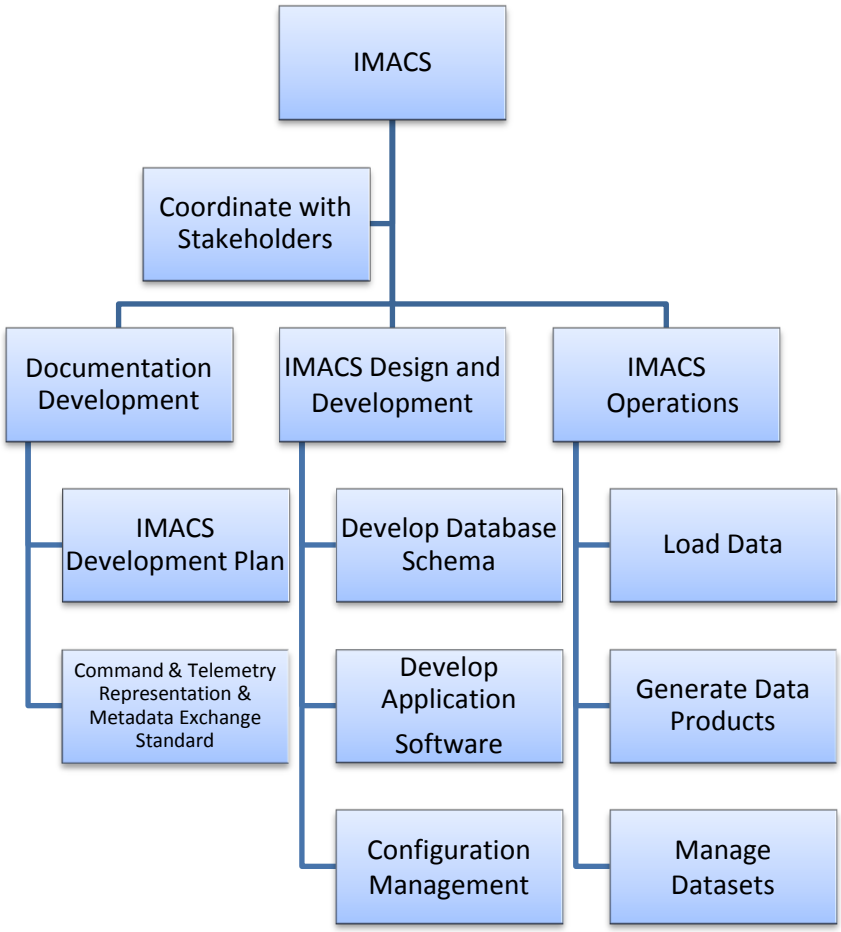

Figure C-1 Top-Level IMACS Activities

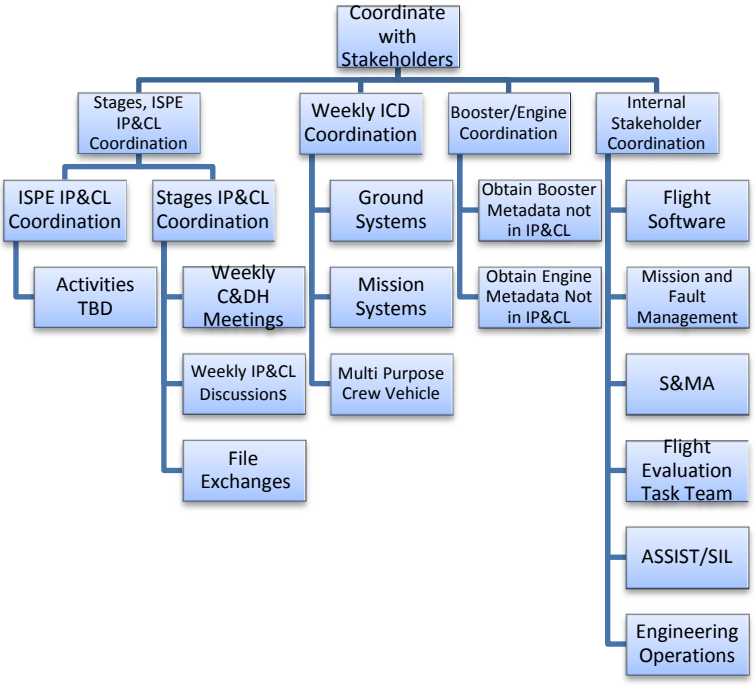

Figure C-2 IMACS Stakeholder Coordination Activities

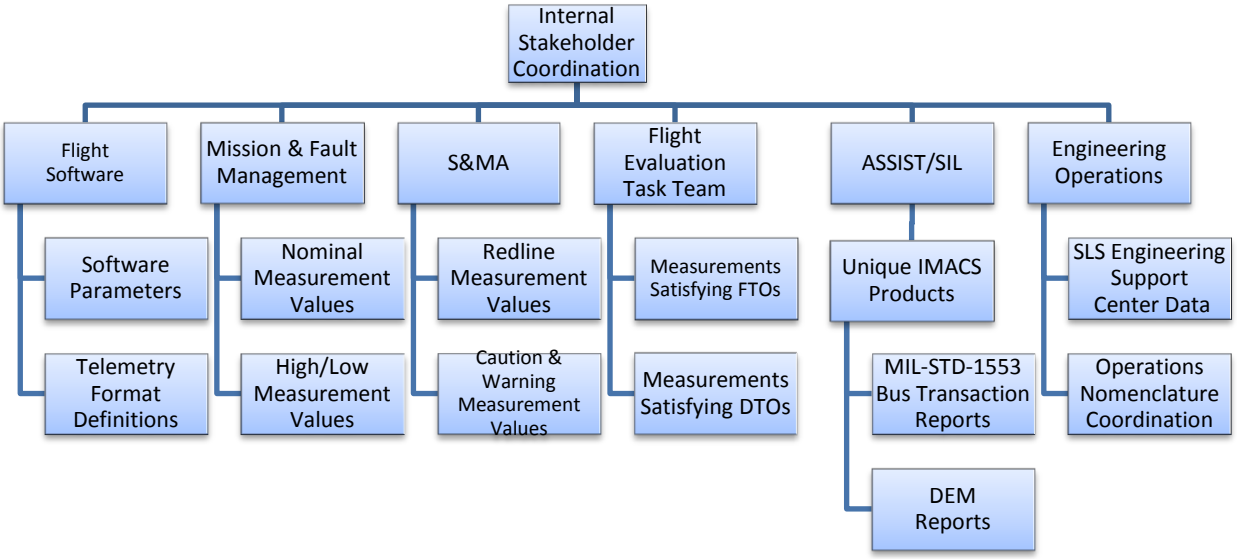

Figure C-3 IMACS Internal Stakeholder Coordination

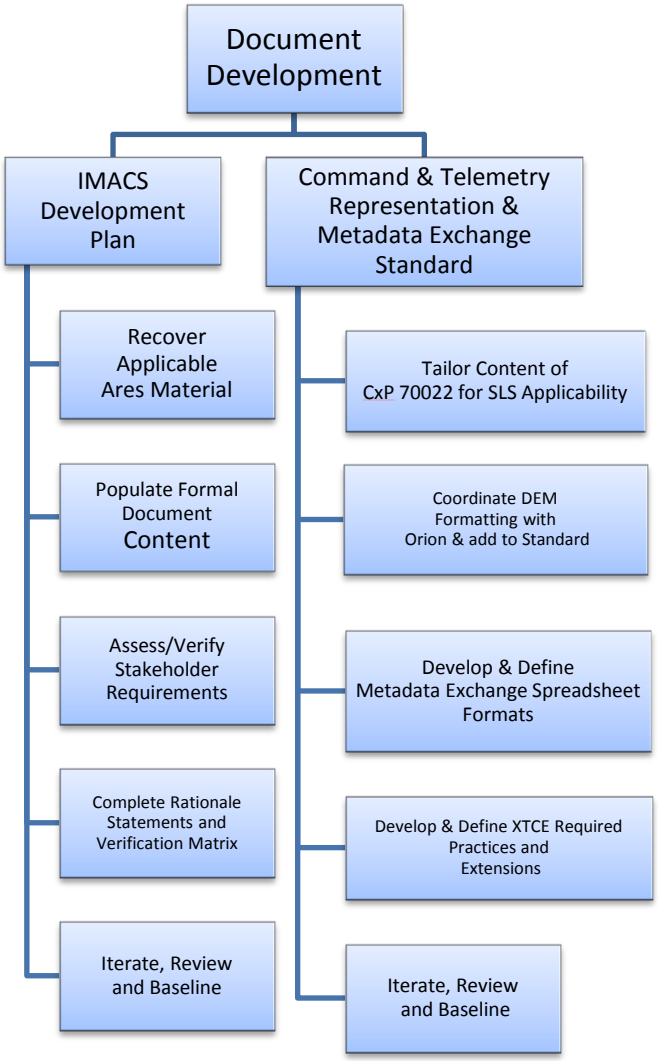

Figure C-4 IMACS Document Development Activity

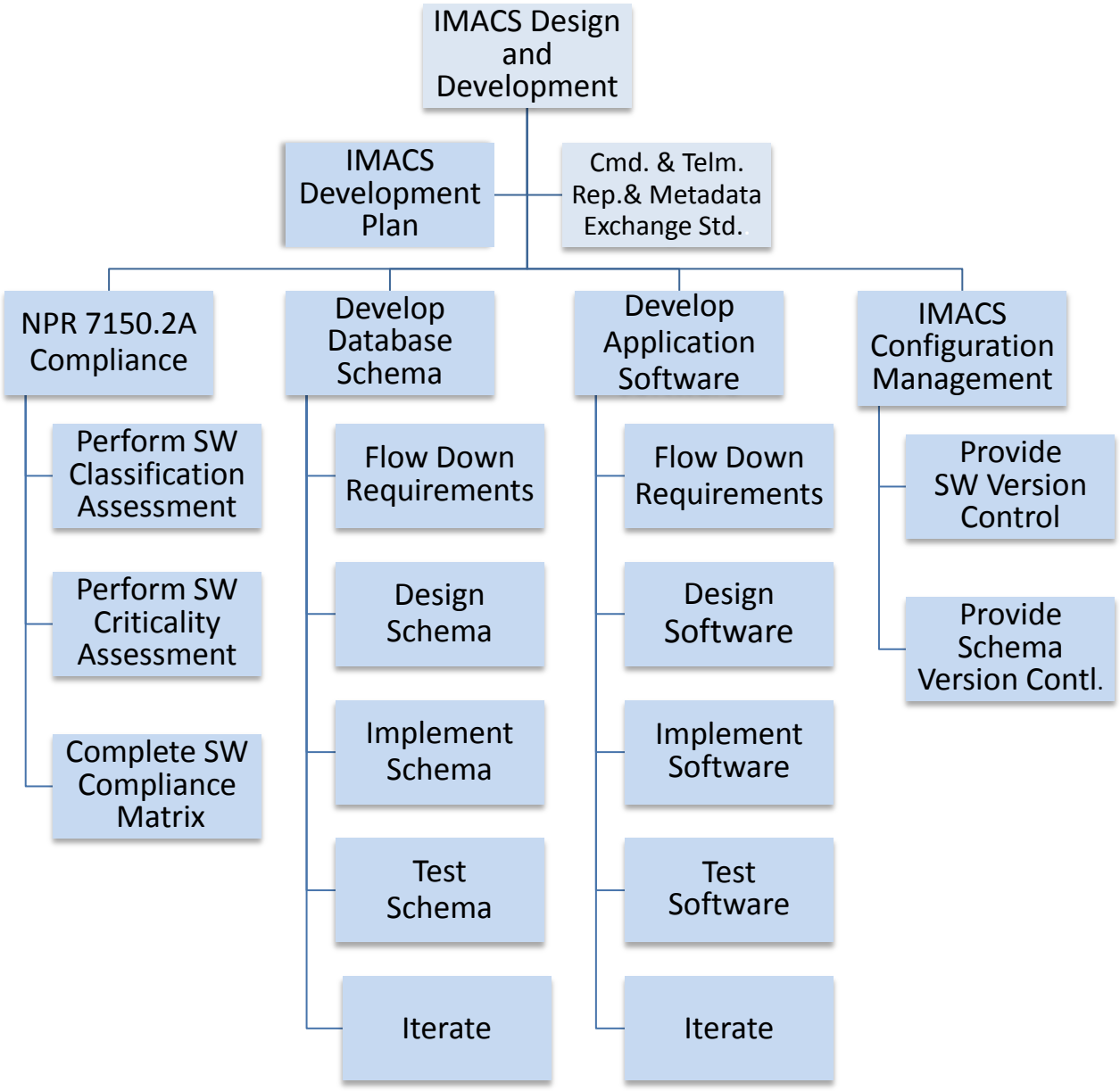

Figure C-5 IMACS Design and Development Activity

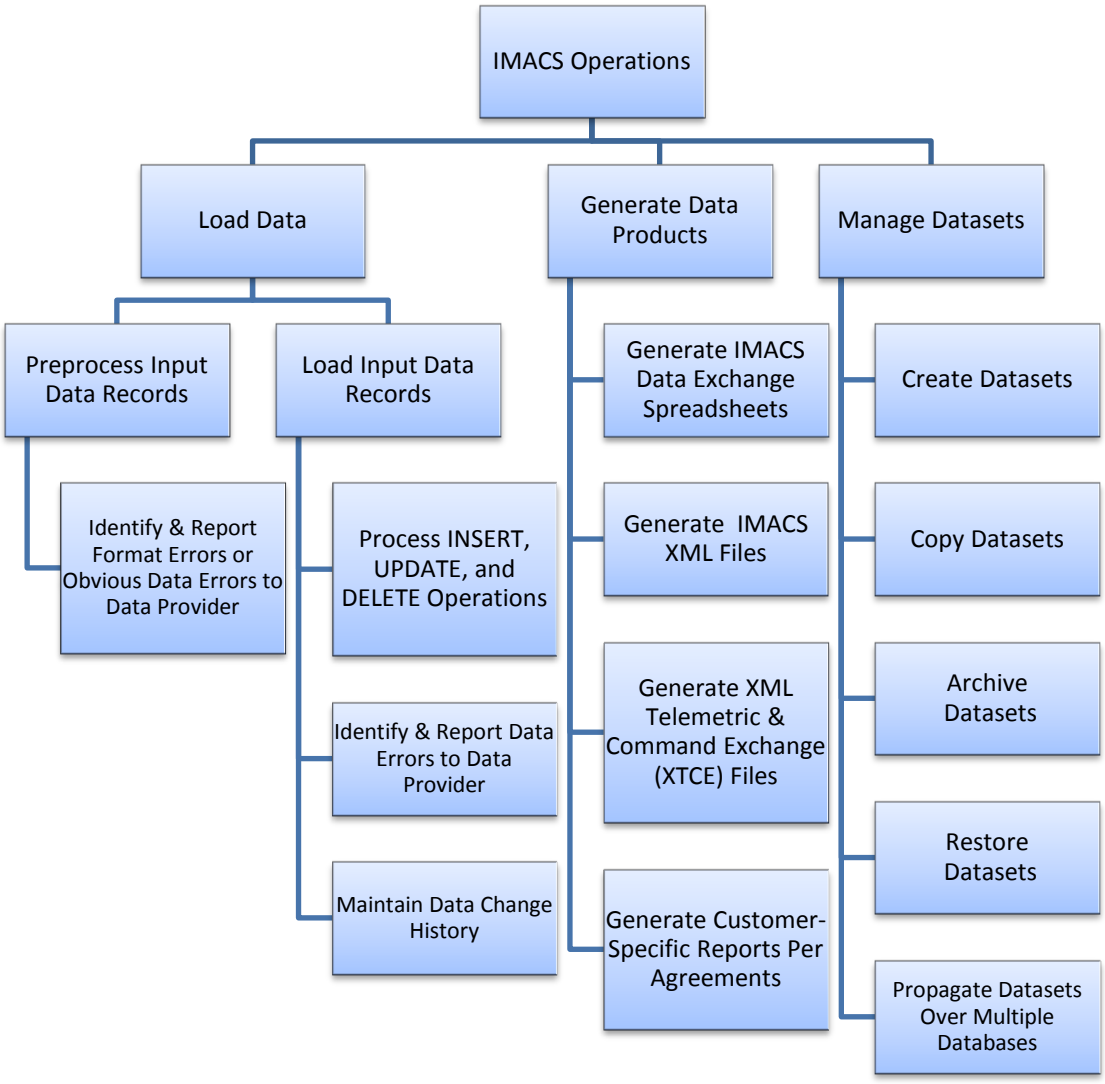

Figure C-6 IMACS Activities During IMACS Operations

APPENDIX D

MPR 7150.1 COMPLIANCE MATRIX <TBD-003>

MPR Section	MPR Descriptor	MPR #	NPR SWE #	Responsibility	Classes C and Safety Critical	Technical Authority by Requirement	Document Showing Compliance
Software Management	Cost estimation	3.1.1.1a	15	Project	X	SwTA	
	Schedule	3.1.1.1b	16	Project	X	SwTA	
	Training	3.1.1.1c	17	Project	X	SwTA	
	Status Reviews	3.1.1.1d	18	Project	X	SwTA	
	Software development life cycle or model	3.1.1.1e	19	Project	X	SwTA	
	Plan tracking	3.1.1.1f	24	Project	X	SwTA	
	Corrective action	3.1.1.1g	25	Project	X (SO if D-E)	SwTA	
						ETA	
	Changes	3.1.1.1h	26	Project	X	SwTA	
	Software classification	3.1.1.2a	20	Project	X	HQ CE	
	Software classification changes	3.1.1.2b	21	Project	X	SwTA	
	"Shall" statements in NPR	3.1.1.2.1	139	Project, Center	X	HQ CE	
	Meeting "P(Center)"	3.1.1.2.1	140	Project, Center	X	HQ CE	
	CMMI levels for class A, B and C software	3.1.1.3	32	Project	Tailored (C only; not required for D and E)	HQ CE	
	Software processes	3.1.1.4	36	Project	X	SwTA	
	Acquisition Assessment	3.1.2.1a	33	Project	X	SwTA	
	Acquisition planning	3.1.2.1b	38	Project	X	SwTA	
	Solicitation	3.1.2.2a	48	Project	X	SwTA	
	Joint audits	3.1.2.2b	45	Project	X	SwTA	
	Insight into software activities	3.1.2.3a	39	Project	⊗	SwTA	
	Access to software products	3.1.2.3b	40	Project	⊗	SwTA	
	Open source notification	3.1.2.3	41	Project	X	SwETA	
		3.1.2.3c				SwTA	

Electronic access to Source code	3.1.2.3 3.1.2.3d	42	Project	X	SwETA SwTA	
Track change request	3.1.2.3e	43	Project	⊗	SwTA	
Software measurement data	3.1.2.3f	44	Project	X	SwTA	
Software schedule	3.1.2.3g	46	Project	X	SwTA	
Traceability data	3.1.2.3 3.1.2.3h	47	Project	X	SwETA SwTA	
Acceptance criteria	3.1.2.4a	34	Project	X	SwTA	
Supplier selection	MSWE- 3.1.2.4b	35	Project	X	SwETA SwTA	
Software Milestones	3.1.2.4c	37	Project	X	SwTA	
COTS, GOTS, MOTS, etc.	3.1.3.1a-e	27	Project	X	SwTA	
Verification planning	3.1.4.1	28	Project	X	SwTA	
Validation planning	3.1.4.1	29	Project	X	SwTA	
Verification results	3.1.4.2	30	Project	X	SwTA	
Validation results	3.1.4.2	31	Project	X	SwTA	
Peer Review/inspections of Software Plans	3.1.4.3a-e	137	Project	⊗	SwTA	
Software inspection/peer review/ inspections content	3.1.4.3a-i	119	Project	⊗	SwTA	
Peer Review - Requirements, test plans, design & code	3.1.4.3f-i	87	Project	X	SwTA	
Peer ReviewChecklist, criteria & tracking	3.1.4.4a 3.1.4.4b	88	Project	⊗	SwTA	
Software plans	3.1.5.1a-e	13	Project	X	HQ CE	
Software development/management plan	3.1.5.1a	102	Project	Tailored	SwTA	
Software configuration management plan	3.1.5.1b	103	Project	⊗	SwTA	
	3.1.5.1	104	Project	⊗	SwETA	
Software test plan	3.1.5.1c				SwTA	
Software maintenance plan	3.1.5.1d	105	Project	X	SwTA	
Software assurance plan	3.1.5.1e	106	Project	X	HQ CE/ CSMAO	
Software assurance	3.1.5.1e	22	Project	X	HQ CE/ CSMAO	
Document maintenance plans	3.1.5.1d	74	Project	X	SwTA	
Develop configuration management plan	3.1.5.1b	79	Project	X	SwTA	

	Execute planning	3.1.5.2	14	Project	X	SwTA	
Software Engineering Life Cycle	Requirements Bi-directional traceability	3.2.1.1a	52	Project	⊗	SwTA	
	Design Bi-directional traceability	3.2.1.1b	59	Project	X	SwTA	
	Code Bi-directional traceability	3.2.1.1c	64	Project	X	SwTA	
	Test Bi-directional traceability	3.2.1.1d	72	Project	X	SwTA	
	Document Software Requirements	3.2.1.2	49	Project	X	SwTA	
	Software requirements specification content	3.2.1.2.1	109	Project	⊗	SwTA	
	Software data dictionary	3.2.1.2.2	110	Project	⊗	SwTA	
	Software requirements	3.2.1.3a	50	Project	X	SwTA	
	Flow-down & derived requirements	3.2.1.3b	51	Project	X	SwTA	
	Manage requirements change	3.2.1.3c	53	Project	X	SwTA	
	Corrective action	3.2.1.3d	54	Project	X	SwTA	
	Requirements validation	3.2.1.3e	55	Project	X	SwTA	
	Document design	3.2.2.1	56	Project	X	SwTA	
	Detailed design	3.2.2.2	58	Project	X	SwTA	
	Software design description content	3.2.2.3	111	Project	⊗	SwTA	
	Interface design description	3.2.2.4	112	Project	Tailored	SwTA	
	Software architecture	3.2.2.5	57	Project	⊗	SwTA	
	Design into code	3.2.3.1a	60	Project	X	SwTA	
	Coding standards	3.2.3.1b	61	Project	X	SwTA	
	Unit test	3.2.3.2	62	Project	X	SwTA	
	Version description document	3.2.3.3a	63	Project	X	SwTA	
	Version description content	3.2.3.3b	116	Project	Tailored	SwTA	
	Plan, procedures, reports	3.2.4.1a	65	Project	X	SwTA	
	Software Test Procedures	3.2.4.1b	114	Project	X	SwTA	
	Software test report content	3.2.4.1c	118	Project	Tailored	SwTA	
	Perform testing	3.2.4.2a	66	Project	X	SwTA	
	Verify implementation	3.2.4.2b	67	Project	X	SwTA	
	Evaluate test results	3.2.4.2c	68	Project	X	SwTA	

	Document defects & track	3.2.4.2d	69	Project	X	SwTA	
	Update plans & procedures	3.2.4.2e	71	Project	X	SwTA	
	Platform or hi-fidelity simulations	3.2.4.2f	73	Project	X	SwTA	
	Static analysis	3.2.4.2g	135	Project	X	SwTA	
	Validation of software development tools	3.2.4.2h	136	Project	X	SwTA	
	Models, simulations, tools	3.2.4.3	70	Project	X	SwTA	
	Plan operations, maintenance & retirement	3.2.5.1	75	Project	X	SwTA	
	Implement plans	3.2.5.1	76	Project	X	SwTA	
	Deliver software products	3.2.5.2a	77	Project	X	SwTA	
	As-built documentation	3.2.5.2b	78	Project	X	SwTA	
	Software users manual	3.2.5.2c	115	Project	X	SwTA	
Software Life Cycle Support	Track & evaluate changes	3.3.1.1a	80	Project	X	SwTA	
	Identify software configuration items	3.3.1.1b	81	Project	X	SwTA	
	Authorizing changes	3.3.1.1c	82	Project	X	SwTA	
	Maintain records	3.3.1.1d	83	Project	X	SwTA	
	Configuration audits	3.3.1.1e	84	Project	X	SwTA	
	Implement procedures	3.3.1.1f	85	Project	X	SwTA	
	Software change request/ problem report	3.3.1.1g	113	Project	⊗	SwTA	
	Continuous risk management	3.3.2.1	86	Project	X	HQ CE/CS MAO	
	Measurement Objectives	3.3.3.1a	90	Project	X	SwTA	
	Software measurement areas	3.3.3.1b	91	Project	⊗	SwTA	
	Measurement Collection & storage	3.3.3.1c	92	Project	X	SwTA	
	Measurement Analyze data	3.3.3.1d	93	Project	⊗	SwTA	
	Measurement Report analysis	3.3.3.1e	94	Project	⊗	SwTA	
	Software metrics report	3.3.3.1f	117	Project	⊗	SwTA	
	Independent Software Classification Assessment	3.3.4.1	132	SMA organization	X	HQ CE/CS MAO	
	Software safety determination	3.3.4.1	133	Project & SMA organization	X	HQ CE/CS MAO	
	Software safety	3.3.4.2a	23	Project	X	HQ CE/ CSMAO	
	Software safety plan	3.3.4.2b	130	Project	X	HQ	

						CE/CS MAO	
	Software safety plan content	3.3.4.2b	138	Project	X	HQ CE/CS MAO	
Compliance	Compliance matrix	3.4.1	125	Project	X	HQ CE	
Waivers /Deviations	Submit generic waiver request	3.5.1a	120	Center or Project	X	HQ CE	
	Document approved alternate requirements	3.5.1b	121	Center or Project	X	HQ CE	
	Center level Engineering Technical Authority approval	3.5.2 and MPR 7120.1	122	Center Director	X	HQ CE	
	Considerations for waivers	3.5.2.1a-f	126	SwTA	X	HQ CE	
	Compliance records	3.5.3	128	Center ETA	X	HQ CE	
	Legend:	⊗ = Fully Implemented "P (Center)" Requirement					
		Tailored = Tailored "P (Center)" Requirement					

APPENDIX E

OPEN WORK

E1.0 TO BE DETERMINED

Table E1-1 lists the specific To Be Determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is sequentially numbered as applicable (i.e., **<TBD-001>** is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBDs will not be renumbered.

Table E1-1. To Be Determined Items

TBD	Section	Description
TBD-001	3.6	Rationale statements for requirements must be completed.
TBD-002	4.3.1	The verification matrix must be completed
TBD-003	Appendix D	The entire MPR 7150.1 compliance matrix must be completed

E2.0 TO BE RESOLVED

Table E2-1 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBR issue is sequentially numbered as applicable (i.e., **<TBR-001>** is the first unresolved issue assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

Table E2-1. To Be Resolved Issues

TBR	Section	Description
TBR-001	3.6.1	An authoritative definition of mission phases, sub-phases, modes and events must be provided by the Program before this requirement can be implemented.