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NASA TECHNICAL HANDBOOK

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Superseding NASA-HDBK-0008

NASA DIGITAL ENGINEERING ACQUISITION FRAMEWORK HANDBOOK

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FOREWORD

This NASA Technical Handbook is published by the National Aeronautics and Space Administration (NASA) as a guidance document to provide engineering information; lessons learned; possible options to address technical issues; classification of similar items, materials, or processes; interpretative direction and techniques; and any other type of guidance information that may help the Government or its contractors in the design, fabrication/assembly, construction, procurement selection, management, support, or operation of systems, products, processes, or services.

This NASA Technical Handbook is approved for use by NASA Headquarters and NASA Centers and Facilities. It may also apply to the Jet Propulsion Laboratory (a Federally Funded Research and Development Center [FFRDC]), other contractors, recipients of grants and cooperative agreements, and parties to other agreements only to the extent specified or referenced in applicable contracts, grants, or agreements.

This NASA Technical Handbook provides guidance for establishing NASA's digital engineering acquisition framework that includes contractual language for Statements of Work and Data Requirements Descriptions (DRDs) in support of a digital engineering environment. It provides information referencing topics such as DRDs, model-based data definition (e.g. model-driven engineering [MDE]), digital data collaboration, architecture, interoperability standards, and general guidance to adapt the methods needed to implement digital engineering environments with support for model-based product/data acquisition requirements.

Requests for information should be submitted via "Feedback" at https://standards.nasa.gov. Requests for changes to this NASA Technical Handbook should be submitted via MSFC Form 4657, Change Request for a NASA Engineering Standard.

Original Signed By	**April 1, 2020**
Ralph R. Roe, Jr. NASA Chief Engineer	Approval Date

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NASA DIGITAL ENGINEERING ACQUISITION FRAMEWORK HANDBOOK

1. SCOPE

1.1 Purpose

This NASA Technical Handbook provides guidance for establishing NASA's digital engineering acquisition framework that includes Data Requirements Descriptions (DRDs) and contractual language for the Statement of Work (SOW) in support of a digital engineering environment (DEE).

A DEE will modernize how the Agency conceptualizes, designs, develops, delivers, operates, and sustains systems. A DEE will help enable collaborative digital engineering while integrating stakeholders with authoritative decentralized sources of data and models seamlessly across organizations and disciplines supporting life-cycle activities from concept through disposal.

Digital engineering is the integrated digital approach that utilizes authoritative sources for product and system data and associated models collaboratively across all product-involved disciplines supporting life-cycle activities from conceptualization through disposal (Pre-Phase A through F). A DEE enables the interconnected data, people, processes, and technology used to store, access, analyze, and visualize evolving systems' data and models to address the needs of enterprise-wide stakeholders. It provides information referencing topics such as model-based definitions (MBD) (annotated 3D CAD models), model-based analyses (MBA), model-based systems engineering (MBSE), model-based enterprise (MBE) (aiding manufacturers to integrate system, service, product, process, and logistics models across the manufacturing/support enterprise), product data and life-cycle management (PDLM), and general guidance to adapt the methods needed to implement digital engineering product/data acquisition requirements maximizing model representations. This NASA Technical Handbook supersedes NASA-HDBK-0008, NASA Product Data and Life-Cycle Management (PDLM) Handbook.

A process for management of technical data is required by NASA Procedural Requirements (NPR) 7123.1, NASA Systems Engineering Processes and Requirements, for ensuring that the data required are captured and stored, data integrity is maintained, and data are disseminated as required. A digital engineering acquisition framework requires that information technology (IT) systems across NASA be made interoperable or federated to the extent needed to provide a secure, readily accessible environment to enable required collaborative digital engineering capabilities. This framework augments PDLM and addresses the acquisition, retrieval, usage, and storage of all program/project data in addition to the technical data used in the life cycle of a system.

Implementing a digital, model-based acquisition framework negates much of the traditional document-centric approach in lieu of a digital engineering environment where digital models hold the information once housed in documents to meet the program/project's decision or information needs in addition to supporting the product-related activities. To achieve the highest level of collaboration, interoperability, efficiency, and data availability, the implementation of a fully digital model-based acquisition framework environment is necessary. A model-based acquisition framework is intended to increase the probability of mission success by increasing the availability, effectiveness, and efficiency of data interchange and integration across like as well as disparate systems for availability of the right data to the right people at the right time, thereby enabling the right decisions and reducing risk.

1.2 Applicability

This NASA Technical Handbook is applicable to the complete program/project life cycle of current and future NASA space flight single-project and tightly coupled programs and their projects as defined in NPR 7120.5, NASA Space Flight Program and Project Management Requirements, and is recommended as guidance in all other programs/projects. The example DRDs in this NASA Technical Handbook should be modified to meet each program/project's and product's needs.

This NASA Technical Handbook is approved for use by NASA Headquarters and NASA Centers and Facilities. It may also apply to the Jet Propulsion Laboratory (JPL) (a Federally Funded Research and Development Center [FFRDC]), other contractors, recipients of grants and cooperative agreements, and parties to other agreements only to the extent specified or referenced in their applicable contracts, grants, or agreements.

This NASA Technical Handbook, or portions thereof, may be cited in contract, program, and other Agency documents[1].

2. APPLICABLE DOCUMENTS

2.1 General

None.

2.2 Government Documents

None.

[1] NPR 7120.10, Technical Standards for NASA Programs and Projects

2.3 Non-Government Documents

None.

References are provided in Appendix K.

2.4 Order of Precedence

2.4.1 The guidance established in this NASA Technical Handbook does not supersede or waive existing guidance found in other Agency documentation.

2.4.2 Conflicts between this NASA Technical Handbook and other documents are to be resolved by the delegated Technical Authority(ies).

3. ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

See Appendix H.

4. DIGITAL ENGINEERING ENVIRONMENT ENABLING DIGITAL DATA ACQUISITION

A digital engineering environment enabling digital data acquisition is, in its simplest form, an environment that encompasses the collaboration of digital project and technical product data among participants. This environment will enable stakeholders to interact with digital tools and technologies largely built on the premise of MBE practices and methods.

A digital engineering acquisition framework consists of disciplined, collaborative processes and systems that plan for, acquire, and control the interoperable flow of product definition data (PDD), product configuration information (PCI), including associated product-related data (metadata) that includes systems engineering, product engineering, design, test, procurement, manufacturing planning, operational, maintenance, and sustainment information throughout the product and data life cycles. A digital engineering acquisition framework is the set of processes that defines and utilizes associated information used to manage and execute the entire life cycle of product data from its conception, through design, test, and manufacturing, to service and eventual disposal. To do so requires managing the creation and changes to product data, levels of model maturity, product configurations, affiliated engineering data, data on the performance of the product components in mission environments, and product software and hardware. It integrates definition and product development data, processes (elements), tools, and business and analytical systems to provide users with a digital product information backbone for defining product configuration information in support of NASA programs/projects.

An acquisition framework creates the foundation and baseline from which the digital engineering environment in an MBE for NASA programs and projects should be driven.

To effectively execute a digital acquisition framework, the following key areas must be applied:

a. Model-Based Data Definition (refer to Appendix C in this NASA Technical Handbook).

b. Digital Data Collaboration (refer to Appendix D in this NASA Technical Handbook).

c. Architecture (refer to Appendix E in this NASA Technical Handbook).

d. Interoperability Standards (refer to Appendix F in this NASA Technical Handbook).

e. Contractual Data Acquisition via Data Requirements Descriptions (DRDs) (refer to section 5 and Appendices A and B in this NASA Technical Handbook).

The assignment of Lead Systems Integrators is essential to ensure the completeness and accuracy of the integrated data/model sets. The systems integrator's responsibility to develop integrated model sets is imperative to ensure consistency is in place and deliverables are clearly defined and adhered to.

A digital/model-based enterprise (see Figure 1, Digital/Model-based Functional Integration) further encompasses and enables the digital exchange of data among the various organizations supporting the entire products' life cycle with its related activities from Pre-Phase A (concept/studies) through Phase F (closeout/disposal).

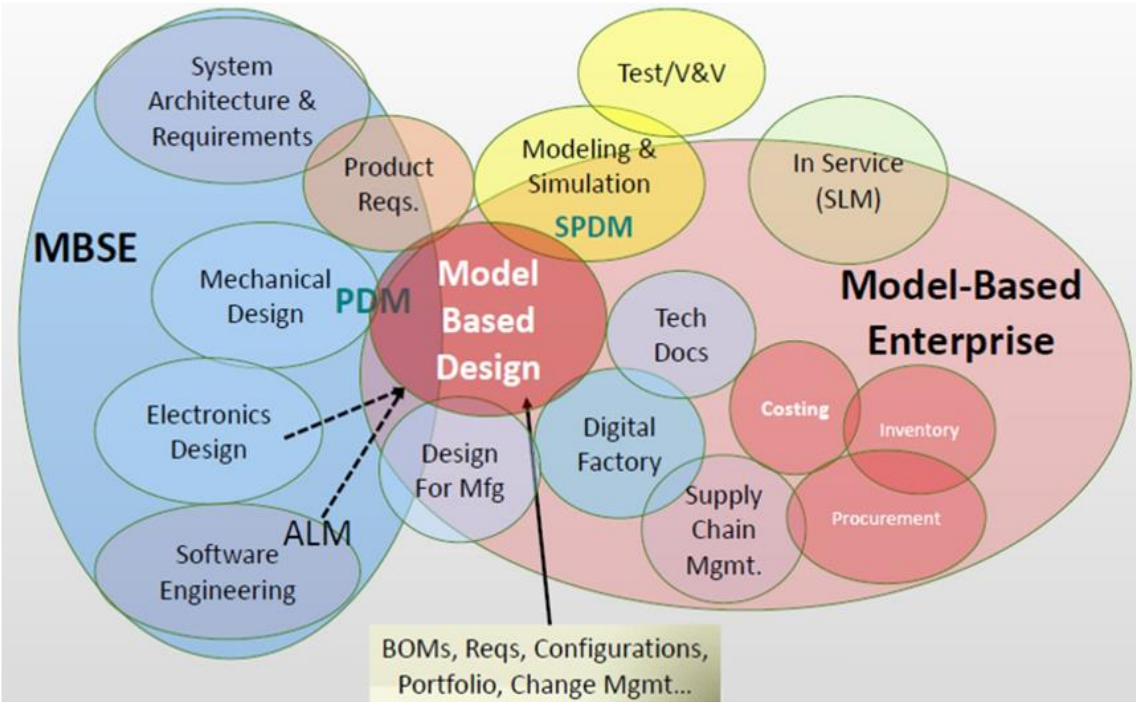

Figure 1—Digital/Model-based Functional Integration (Source: CIMdata)

Refer to Appendix I for additional information.

5. DATA REQUIREMENTS DESCRIPTIONS (DRDs) FOR CONTRACTUAL DATA ACQUISITION

Digital engineering acquisition DRDs contain the contract language and associated standards necessary to execute digital data interoperability and provide collaboration governance, contract definition, and enforcement to properly define key decision point (KDP) deliverables. DRDs should fully describe the required data items (e.g. MBx models, documents, reports, and/or drawings) by providing its purpose (description/use), content, format, maintenance, submittal, etc., requirements.

Introduction of such contract language can ensure that data acquisitions are appropriately included into NASA contracts, guaranteeing the Government does not lose data, information, or knowledge produced during the contract and, ultimately, lowering cost and effort for both parties. Considerations are also made to ensure that the Government has access to data developed throughout the contract period and that information is effectively transferred/available to the various communities involved. Specific language needs to be implemented within several sections of the Request for Proposals (RFP) to enable this level of data definition, integrity, control, and access during and after the contract is put in place.

Several pertinent DRDs are provided in Appendix A as a starting point for NASA organizations to define their specific needs for digital engineering.

Appendix B provides guidance in developing data acquisition contract language.

APPENDIX A

DATA REQUIREMENTS DESCRIPTIONS (DRDs)

A.1 PURPOSE

This Appendix provides recommended example DRDs for supporting digital and model-based acquisitions are as follows:

- DRD Purpose and Instructions. (Refer to A.2.)
- Technical Data Package (TDP). (Refer to A.3.)
- Engineering Model-based x (MBx) Models and Associated Data. (Refer to A.4.)
- Configuration and Data Management Process Audit (CMPA) (Refer to A.5.)
- Configuration and Data Management Plan (CDMP) (Refer to A.6.)
- Configuration Status Accounting (CSA) (Refer to A.7.)
- Specification and Drawing Trees (SDT) (Refer to A.8.)
- Engineering Models, Drawings, and Associated Lists (EMDAL) (Refer to A.9.)
- Change Request (CR) (Refer to A.10.)
- Functional Configuration Audit/Physical Configuration Audit Documentation (AD) (Refer to A.11.)
- Requirements Exchange Format (REF) (Refer to A.12.)
- Master Records Index (MRI) (Refer to A.13.)
- Contract Language for Data Acquisition and Interoperability (Refer to A.14.)
- Recommended Configuration Management (CM) Statement of Work Section for Contractors (Refer to A.15.)

The purpose of, and instructions for, utilizing, and examples of DRDs with example content are provided on the following pages. The choice to use specific DRDs and the content included on those DRDs needs to be selected and tailored by each acquirer (program, project, etc.) and likely needs inclusion of additional DRDs for their given agreement. Acquirer should emphasize and maximize the use of Agency approved or endorsed standards, neutral formats, etc., and avoid specifying specific vendor or proprietary formats wherever possible.

A.2 DATA REQUIREMENTS DESCRIPTION (DRD) PURPOSE AND INSTRUCTIONS

PURPOSE OF THE DRD

The DRD should fully describe a deliverable data item (e.g. model, database, item/object, document, report, etc.) by providing the specified purpose, content, format, compliance standards, maintenance, and submittal requirements levied upon the Contractor. The delivered data item will enable assimilation into the receiving organizations' information systems/tools with little or no post-receipt processing (beyond the data item's verification). The DRD examples provided are for a contract data requirement; however, a DRD may be used for an inter-Agency (Supplier) agreement with some tailoring. The DRD defines the requirements the Contractor/Supplier is contractually obligated to meet when preparing and submitting the data item described by the DRD. All DRDs for a particular contract are combined/assembled in one Data Procurement Document (DPD). The DPD is an attachment to the contract and a companion document to the Statement of Work (SOW) or Performance Work Statement (PWS). Each DRD should be invoked by relevant SOW or PWS language included in its applicable section.

Following is an explanation of each item on the example DRD:

DRD ITEM **EXPLANATION**

1. **DPD/DRL NO.:** Indicates the unique number assigned to the Data Procurement Document (DPD)/Data Requirements List (DRL) of which this DRD is part. DPD/DRL numbers for each contract DPD are obtained from the [Enter Agency/Program] Data Requirements Manager (DRM). Control Processes/Approval Authority for DRLs are defined in the Data Management Plan and/or Statement of General Requirements (SGR) for that program/project.

2. **DPD STATUS:** Indicates the status of the DPD/DRL (e.g. Draft, RFP, New, Subsequent Revision).

3. **DRD NO.:** Indicates the unique DRD identification number, which is comprised of (1) three- or four-digit DPD number; (2) two-letter Data Category designation (refer to Table 1, Data Category Designations); and (3) three-digits assigned sequentially within the Data Category. Data Categories may be tailored per task application.

Table 1—Data Category Designations

CD - Contractual Data	HE – Human Engineering	QE - Quality Engineering
CM - Configuration Management	LS - Logistics Support	RM - Reliability and Maintainability
DE - Design and Development Engineering	MA - Management	SA– Safety
DM - Data Management	MP - Materials and Processes	SE - Systems Engineering
EE - Environmental	OP - Mission Operations	SW - Software

4. **<u>DATA TYPE</u>:** Provides a code number(s) that corresponds to the approval requirements for the submitted data item. Enter the type of data (refer to Table 2, Data Types for Contractor Deliverables) according to the contractually applicable requirements, e.g. 1, 2, 3, etc. Data Types and approval requirements for each data type are defined in the DPD SGR.

Table 2—Data Types for Contractor Deliverables

The data type indicates the level of Government control to be applied.	
Type 1	All issues and interim changes to those issues require written approval from the requiring organization before formal release for use or implementation. **APPLICATION NOTE:** Because Type 1 data requires Center approval before use, if Contractor-produced data is to be placed under Center Configuration and Data Management (CDM) control as part of the Center baseline, the data should be designated as Type 1.
Type 2	NASA reserves a time-limited right to disapprove in writing any issues and interim changes to those issues. The Contractor shall: a. Submit the required data to NASA for review not less than 45 calendar days** prior to its release for use. The submittal is considered approved if the Contractor does not receive a disapproval or an extension request from NASA within 45 calendar days**. b. Clearly identify the release target date in the "submitted for review" transmittal***. If the data is unacceptable, NASA will notify the Contractor within 45 calendar days** from the date of submission, regardless of the intended release date***. c. Resubmit the information for reevaluation if disapproved. ****APPLICATION NOTE:** This 45-day time limit may be tailored for individual DRDs to meet the requirements of the procuring activity. *****APPLICATION NOTE**: If the Contractor does not identify a release target date or if the intended release date is shorter than 45 calendar days from the date

	of submission, the 45-calendar-day review cycle stands (or the tailored Type 2 time limitation for the specific procurement).
Type 3	These data shall be delivered by the Contractor as required by the contract and do not require NASA approval. However, to be a satisfactory delivery, the data shall satisfy all applicable contractual requirements and be submitted on time.
Type 4	These data are produced or used during performance of the contract and are retained by the Contractor. They are delivered only when NASA requests in writing and in accordance with the instructions in the request. The Contractor shall maintain a list of these data and shall furnish copies of the list to NASA when requested. **APPLICATION NOTE:** Federal Acquisition Regulations 48 CFR § 52.227-16, Additional Data Requirements, has to be included in the contract to get delivery of this data.
Type 5	These data are incidental to contract performance and are retained by the Contractor in those cases where contracting parties have agreed that formal delivery is not required. However, the Contracting Officer or the Contracting Officer's Representative shall have access to and can inspect this data at its location in the Contractor's or subcontractor's facilities or in an electronic database accessible to the Government.

5. **DATE REVISED:** Indicates the date the DRD was revised after contract award via contract modification. "Date Revised" will contain a date only if the DRD was revised after contract award. Prior to contract award, this item should be blank.

6. **PAGE:** Indicates the current DRD page number and total number of pages in the DRD.

7. **TITLE:** Indicates the title of the data requirement described by this DRD.

8. **DESCRIPTION/USE:** Indicates a brief description and/or purpose for the data item described by this DRD. One or two sentences are often adequate.

9. **OPR:** Indicates the Office of Primary Responsibility (OPR) organization designated to exercise technical or administrative control over the data requirement. The OPR code does not necessarily indicate the organization code for the data item reviewer(s), typically the subject matter expert(s) (SME) for data item(s).

10. **DM:** Indicates the organization code for the Data Manager (DM) (for program/project) or Center organization procuring the data. Enter the appropriate DM code, e.g. ENB XX, CM YY, QUAL ZZ, etc. The DM is usually selected by the project office and represents this office on formal data requirements. The DM organization typically receives and subsequently processes (distributes, etc.) the submittals.

11. **DISTRIBUTION**: Indicates the distribution requirements for the delivered data item. Individual organization codes or a separate distribution matrix may be referenced here for specific DRD deliverables. If "Per Contracting Officer's letter" is indicated, the Contracting Officer will provide specific distribution requirements to the Contractor via a separate letter. This method is preferable because it does not necessitate a contract modification to change distribution requirements.

12. **INITIAL SUBMISSION:** Indicates the submittal due date for the first submission of the data item to be prepared in response to this DRD. The due date should be a milestone rather than a specific calendar date (e.g. "30 days after contract award" instead of "January 5, 2006") to better accommodate schedule changes.

13. **SUBMISSION FREQUENCY:** Indicates when the submission is due (e.g. "Critical Design Review") or frequency (e.g. monthly, quarterly) for subsequent submissions of the data item to be prepared/delivered in response to this DRD. These due dates should also be milestones instead of calendar dates.

14. **REMARKS:** Provides reference/guideline documents/information and special instructions/remarks to the Contractor/Supplier not included elsewhere on this DRD. It is acceptable to have no entry or "NA" (not applicable) under "Remarks."

15. **INTERRELATIONSHIP:** Indicates Statement of Work (SOW) or Performance Work Statement (PWS) paragraph numbers, other portions of the contract, or other DRDs in the DPD that reference or interrelate with this requirement (e.g. "SOW paragraph 4.3," "DRD XXXMP-001").

16. DATA PREPARATION INFORMATION

16.1 **SCOPE:** Provides a short summary of the content of the data item to be prepared and submitted in response to this DRD.

16.2 **APPLICABLE ITEMS:** Provides documents, sources, templates, etc.—those items applicable to the preparation of the data item requested by this DRD. Applicable items should provide content and/or format requirements for the deliverable data item in accordance with specified standards or provided templates. The applicable items have to be referenced in DRD sections 16.3 or 16.4 to indicate how they apply to the preparation of the item.

16.3 **CONTENTS:** Defines the required scope and contents of the data item to be prepared in response to this DRD. Applicable items providing content requirements may be referenced here or specific content requirements may be delineated. Applicable items should be referenced here, if appropriate, with specific application, i.e. “The data shall be prepared in accordance with YYY-STD-XXXX, Section X, paragraph X.X.X.”

16.4 **<u>FORMAT</u>:** Provides the required format of the data item to be prepared in response to this DRD. Applicable items providing format requirements may be referenced here or specific format requirements may be delineated. Applicable items should be referenced here, as appropriate, with specific application, i.e. “The data shall be prepared and submitted in accordance with YYY-STD-XXXX, Section X, paragraph X.X.X.” or “The data shall be prepared and submitted using Government-provided template YYY.YY.” “Contractor format is acceptable” should almost never be used—only if/when there is no specific Government format required and only after it has been approved in advance by the Government.

16.5 **<u>MAINTENANCE</u>:** Indicates if and how the data item will be maintained current (e.g. “Changes shall be incorporated by change page or complete reissue” for plans). If the data item is a recurring report, the maintenance statement will be “None required,” because reports are replaced by the next report submission. If the data item is a plan or specification that will be maintained current, the maintenance statement should be “Changes shall be incorporated by change page or complete reissue.”

17. Other items such as Related Data Deliverables may be added.

A.3 TECHNICAL DATA PACKAGE (TDP)

DATA REQUIREMENTS DESCRIPTION (DRD)

1. DPD NO.: XXX **2. DPD STATUS**: Draft **3. DRD NO.**: **STD-TDP**
4. DATA TYPE: 2/3 **5. DATE REVISED**:
6. PAGE: 1/7

7. TITLE: Technical Data Package (TDP)

8. DESCRIPTION/USE: The TDP consists of the technical description of an item suitable for use as the basis for engineering activities, competitive acquisition, production, installation, modification, operations, maintenance, and logistics support of Government material or property developed by or for the Government. The TDP defines the required design configuration ("as-designed" product configuration information), performance requirements, and procedures required to ensure an item's performance. It consists of applicable digital technical data such as models, drawings, associated lists, specifications, standards, performance requirements, quality assurance provisions (QAPs), software, and memory device documentation and packaging/handling details. The TDP data are ingested into the Government's digital environment and serve as the basis for the as-received ("as-sustained") Product Baseline. This DRD relies heavily on DoD's Technical Data Package standard (MIL-STD-31000) to provide requirements for the deliverable TDP data products and its related TDP data management products:

a. Conceptual TDP. A conceptual package is a collection of sketches, low fidelity computer-aided design (CAD) models, and text that document basic concepts of how an item may be developed to meet operational requirements. The TDP is used to determine if the requirements are feasible.

b. Developmental TDP. A developmental package is a collection of data intended to document a specific design approach and the fabrication of a developmental prototype for test or experimentation. These data elements capture the basic design of equipment/systems developed from a concept. They are not intended, nor are they adequate, for use in the competitive procurement of component parts.

c. Product TDP. A product package is a collection of product engineering data related to the design and manufacture of an item or system. Product drawings and/or CAD models contain all of the descriptive documentation needed to ensure the competitive procurement of spare parts or end items.

d. Commercial TDP. A commercial package is for end items developed by the Contractor prior to the award of the contract at his/her own expense. Unless the

Government purchases rights for these drawings and/or CAD models, these data sets provide the Contractor's proprietary engineering and design information for commercially developed items, off-the-shelf items, or items not developed at Government expense.

(1) This DRD contains the format and content preparation instructions for TDPs resulting from the work task described in MIL-STD-31000B, section 5.3.3.
(2) When this DRD is incorporated, in whole or in part, in a contract, DRDs applicable to individual parts of a TDP shall not be incorporated as separate requirements.

9. OPR: NASA Systems Engineering and Integration (SE&I) Office

10. DM: NASA Configuration Management Office

11. DISTRIBUTION: TBD

12. INITIAL SUBMISSION: Conceptual TDP - within thirty (30) days of contract award.

13. SUBMISSION FREQUENCY: Relative to each Major Milestone representing NPR 7120.5 life-cycle reviews, MIL-STD-31000, section 4.2 TDP levels (conceptual, developmental, production, and commercial) are leveraged to identify the level and type of data package. Interim submittals are to be made available per request up to ninety (90) days prior to a scheduled delivery, with contracted deliveries due thirty (30) days prior to the respective Major Milestone.

a. Conceptual TDP. Initial due within thirty (30) days post contract award with updates due 30 days prior to System Requirements Review (SRR) and the System Definition Review (SDR). Minimally annotated 3D models alone may be sufficient.
b. Developmental TDP. Due ninety (90) days prior to Preliminary Design Review (PDR).
c. Product TDP. Due ninety (90) days prior to Critical Design Review (CDR).
d. Commercial TDP. Initial list of potential Contractor proprietary end items due thirty (30) days post contract award for Government to identify and select potential procurement/data rights items. TDPs for selected items due thirty (30) days prior to PDR.

14. REMARKS: NASA will provide draft TDP delivery schedule and provide interim requests through the Contracting Officer’s Representative to the Contractor within ninety (90) days post contract award.

15. INTERRELATIONSHIPS:

15.1 DRDs (may include the following as specified):

a. DRD No. STD-MBx - Engineering Model-Based x "MBx" Models and Associated Data.
b. DRD No. STD-SDT - Specification and Drawing Trees.
c. DRD No. STD-EMDAL – Engineering Models, Drawings, and Associated Lists.

16. DATA PREPARATION INFORMATION:

16.1 SCOPE: TDPs contain the required data sets (CAD, analyses, etc., models, metadata, and supporting product configuration information) necessary to support the building of an integrated model set representing the program's top level end items representing the integrated system.

16.2 APPLICABLE ITEM:
MIL-STD-31000 Technical Data Packages

16.3 CONTENTS: The following items provide a technical description of the items necessary for supporting an acquisition, production, engineering, and logistics support (e.g. Engineering Data for Provisioning, Training, and Technical Manuals). TDPs contain multiple elements, described by levels and types, and typically have associated metadata and supplementary technical data. The description defines the required design configuration and/or performance requirements and procedures required to ensure adequacy of an item's performance. It consists of applicable technical data such as models, drawings, associated lists, specifications, standards, performance requirements, QAPs, software documentation, and packaging details. The following contents shall be in accordance with the contract if specified—otherwise with MIL-STD-31000. (Note: Preparer should refer to MIL-STD-31000 for guidance, reference paragraph A.3, and utilize Figure 5 TDP Option Selection Worksheet [attached] as feasible).

16.3.1 REFERENCE DOCUMENTS. The applicable issue of the documents cited herein, including their approval dates and dates of any applicable amendments, notices, and revisions, shall be as specified in the contract.

16.3.2 CONTENT. The TDP shall include one or more of the following:

a. Conceptual design drawings/models in accordance with MIL-STD-31000B, section 5.4.1.1.
b. Developmental design drawings/models and associated lists in accordance with MIL-STD-31000B, section 5.4.1.2.
c. Product engineering design data and associated lists in accordance with MIL-STD-31000B, section 5.4.1.3. The following shall be documented directly or by reference, as applicable:
   (1) Details of unique processes, i.e. not published or generally available to industry, when essential to design and manufacture.

(2) Performance ratings.
(3) Dimensional and tolerance data.
(4) Critical manufacturing processes and assembly sequences.
(5) Toleranced input and output characteristics.
(6) Diagrams.
(7) Mechanical and electrical connections.
(8) Physical characteristics, including form, finishes, and protective coatings.
(9) Details of material identification, including material condition and mandatory treatments and coatings.
(10) Inspection, test, and evaluation criteria.
(11) Equipment calibration requirements.
(12) Quality assurance requirements.
(13) Hardware marking requirements.
(14) Requirements for reliability, maintainability, environmental conditioning, shock and vibration testing, and other operational or functional tests.
(15) Vendor substantiation data when required by the contract or purchase order.
(16) Requirements for programming software into devices or assemblies, including a description of the input media and the procedures for validating that the software has been installed correctly.
(17) Special consideration items and processes.

d. Commercial drawings/models and associated lists in accordance with MIL-STD-31000B, section 5.4.1.4.
e. Special inspection equipment (SIE) drawings/models and associated lists in accordance with MIL- STD-31000B, section 5.4.2.
f. Special tooling (ST) drawings/models and associated lists in accordance with MIL-STD-31000B, section 5.4.3.
g. Specifications in accordance with MIL-STD-31000B, section 5.4.4.
h. Software documentation in accordance with MIL-STD-31000B, section 5.4.5.
i. Special packaging instruction (SPI) documents, drawings/models, and associated lists in accordance with MIL-STD-31000B, section 5.4.6.
j. Quality assurance provisions in accordance with MIL-STD-31000B, section 5.4.7.
k. Technical Data Package List (TDPL). A TDPL shall be prepared as an index to identify all content contained in the TDP. The TDPL format shall be as described in the contract but, as a minimum, shall list all content in the TDP by nomenclature, document number, CAGE code, document revision, and date.

16.4 FORMAT: The Contractor shall ensure that the following standards are implemented to sufficient conformance levels, including industry recommended practices:

a. ASME Y14.41, "Digital Product Definition Data Practices, Engineering Product Definition and Related Documentation Practices."
b. ASME Y14.47, "Model Organization Practices - Engineering Product Definition and Related Documentation Practices."

c. ISO 10303, Part 209, edition 2, "Industrial automation systems and integration - Product data representation and exchange - Part 209: Application protocol: Multidisciplinary analysis and design."
d. ISO 10303-238, "Standard for the Exchange of Product (STEP) Model Data, PART 238: Application interpreted model for computerized numeric controllers."
e. ISO 10303-239, "Industrial automation systems and integration - Product data representation and exchange - Part 239: Application protocol: Product life-cycle Support."
f. ISO 10303-242, "Industrial automation systems and integration – Product data representation and exchange – Part 242: Application protocol: Managed model-based 3D engineering."

Lightweight 3D CAD model representations shall be provided in one or more of the following:

a. ISO 10303-242, "Industrial automation systems and integration – Product data representation and exchange – Part 242: Application protocol: Managed model-based 3D engineering."
b. ISO 14306, "JT file format specification for 3D visualization."
c. ISO 14739-1, "3D use of Product Representation Compact (PRC) format"

16.5 MAINTENANCE: Upon change/update post delivery and models upon request.

Reference MIL-STD-31000B, Figure 5.

TDP OPTION SELECTION WORKSHEET

SYSTEM:		DATE PREPARED:	
A. CONTRACT NO.	B. EXHIBIT/ATTACHMENT NO.	C. CLIN	D. CDRL DATA ITEM NO.

1. TDP LEVEL (CHOOSE ONLY ONE PER WORKSHEET). Note: The level selected must coincide with the requirements of the elements selected in block 5.

A. ☐ CONCEPTUAL LEVEL
☐ DEVELOPMENTAL LEVEL
☐ PRODUCT LEVEL

B. REMARKS:

2. TYPE AND FORMAT (X all that apply and complete as applicable.)

A. ☐ TYPE 2D: 2D DRAWINGS(describe in detail in remarks below or in block 11):

☐ NATIVE 2D CAD (SPECIFY TYPE): ______________________________
☐ ISO 32000 PDF
☐ HARD COPY
☐ OTHER FORMAT (SPECIFY TYPE): ______________________________

REMARKS :

B. ☐ TYPE 3D: 3D MODEL BASED (describe in detail in remarks below or in block 11):

☐ NATIVE 3D CAD (SPECIFY TYPE): ______________________________
☐ 3Di VIEWABLE* FORMAT DERIVED FROM 3D NATIVE MODELS (Specify type, i.e. ISO 32000 PDF etc.).
☐ NEUTRAL FORMAT DERIVED FROM 3D NATIVE MODELS (Specify type, i.e. STEP AP203, AP 214 etc.).
☐ 2D DRAWINGS DERIVED FROM 3D NATIVE MODELS (Specify type, i.e. ISO 32000 PDF etc.).
☐ OTHER FORMAT (SPECIFY TYPE): ______________________________

**NOTE: 3Di viewable will be in ISO 32000 pdf format unless otherwise specified.*

REMARKS :

3. CAGE CODE AND DOCUMENT NUMBERS	A. ☐ CONTRACTOR CAGE & DOCUMENT NUMBERS ☐ GOVERNMENT CAGE & DOCUMENT NO. (COMPLETE 3B, 3C, AND 3D)	
B. USE CAGE CODE:	C. USE DOCUMENT NUMBERS:	D. TO BE ASSIGNED BY:

4. DRAWING FORMATS AND/OR 3Di PDF FORMAT (X one and complete as applicable)

☐ CONTRACTOR FORMAT ☐ GOVERNMENT FORMAT
REMARKS:

5. TDP ELEMENTS REQUIRED (X all that apply)

☐ ELEMENTS REQUIRED TO BE DETERMINED BY CONTRACTOR

OR THE FOLLOWING ARE REQUIRED:

☐ CONCEPTUAL ENGINEERING DESIGN DATA
☐ DEVELOPMENTAL ENGINEERING DESIGN DATA AND ASSOCIATED LISTS
☐ PRODUCT ENGINEERING DESIGN DATA AND ASSOCIATED LISTS
☐ COMMERCIAL ENGINEERING DESIGN DATA AND ASSOCIATED LISTS
☐ SPECIAL INSPECTION EQUIPMENT (SIE) ENGINEERING DESIGN DATA AND ASSOCIATED LISTS
☐ SPECIAL TOOLING ENGINEERING DESIGN DATA AND ASSOCIATED LISTS
☐ SPECIFICATIONS
☐ SOFTWARE DOCUMENTATION
☐ SPECIAL PACKAGING INSTRUCTIONS (SPI) ENGINEERING DESIGN DATA AND ASSOCIATED LISTS
☐ QUALITY ASSURANCE PROVISIONS (QAPs)

6. APPLICABILITY OF STANDARDS. The following Standards apply: (X as applicable)

☐ ASME Y14.100 ENGINEERING DRAWING PRACTICES WITH APPENDICES: ☐ B ☐ C ☐ D ☐ E Company stds permitted? Y/N	☐ ASME Y14.24 TYPES AND APPLICATIONS OF ENGINEERING DRAWINGS ☐ ASME Y14.34 ASSOCIATED LISTS ☐ ASME Y14.35 REVISION OF ENGINEERING DRAWINGS AND ASSOCIATED DOCUMENTS ☐ ASME Y14.41 DIGITAL PRODUCT DEFINITION DATA PRACTICES ☐ ASME Y14.5 DIMENSIONING AND TOLERANCING	☐ OTHER STANDARDS APPLY AS DESCRIBED:

TDP OPTION SELECTION WORKSHEET PAGE 2				
A. CONTRACT NO.	B. EXHIBIT/ATTACHMENT NO.	C. CLIN		D. CDRL DATA ITEM NO.
7. ASSOCIATED LISTS (X all that apply and complete as applicable.)				
A. ☐ PARTS LISTS (X ONE)*	☐ (1) INTEGRAL	☐ (2) SEPARATE		☐ (3) CONTRACTOR SELECT
B. ☐ DATA LISTS	☐ REQUIRED (Specify Levels of ASSY) ______			
C. ☐ INDEX LISTS	☐ REQUIRED (Specify Levels of ASSY) ______			
D. ☐ WIRING LISTS	☐ (1) INTEGRAL	☐ (2) SEPARATE		☐ (3) CONTRACTOR SELECT
E. ☐ APPLICATION LISTS	☐ (1) INTEGRAL	☐ (2) SEPARATE	☐ (3) PLM MAINTAINED	☐ (4) CONTRACTOR SELECT
F. ☐ OTHER	☐ REQUIRED(Specify Levels of ASSY) ______			
*NOTE: USE OF SEPARATE PARTS OR WIRING LISTS ARE NOT RECOMMENDED ESPECIALLY WITH TYPE 3D TDPS.				
8. TDP DATA MANAGEMENT PRODUCTS				
A. ☐ TECHNICAL DATA PACKAGE LIST (TDPL) ☐ SOURCE CONTROL APPROVAL REQUEST ☐ DOCUMENT NUMBER ASSIGNMENT REPORT ☐ PROPOSED CRITICAL MANUFACTURING PROCESS DESCRIPTION ☐ ENGINEERING DRAWING TREE ☐ TO LOWEST REPAIRABLE UNIT (LRU) LEVEL ☐ TO LOWEST COMPONENT LEVEL ☐ OTHER (DESCRIBE): ______			B. REMARKS:	
9. TDP METADATA				
☐ TDP METADATA REQUIRED (describe requirements):				
10. TDP SUPPLEMENTARY DATA				
☐ TDP SUPPLEMENTARY DATA REQUIRED (describe requirements):				
11. OTHER TAILORING (Attach additional sheets as necessary				
12. PROCURING ACTIVITY TITLE, SIGNATURE AND DATE				
TITLE:	SIGNATURE:		DATE:	

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A.4 ENGINEERING MODEL-BASED x (MBx) MODELS AND ASSOCIATED DATA

DATA REQUIREMENTS DESCRIPTION (DRD)

1. **DPD NO.**: XXX 2. **DPD STATUS**: Draft 3. **DRD NO.**: **STD-MBx**
4. **DATA TYPE**: 3 5. **DATE REVISED**:
6. **PAGE:** 1/3

7. **TITLE:** Engineering Model-Based x (MBx) Models and Associated Data

8. **DESCRIPTION/USE:** To provide engineering digital data utilizing model-based definitions (MBD) in a model-based enterprise (MBE) by defining the required design, analyses, and manufacturing models to the extent required to support integration of engineering, manufacturing, assembly/test, operations, maintenance, and sustaining functions of the integrated products and its systems. Engineering MBx models, data sets, and associated metadata shall be sufficient to build/assemble the detailed configuration of all deliverable system, subsystem, and component levels for given purpose (e.g. Digital Mock-up Unit [DMU], integrated Systems Modeling Language™ (SysML™) models, etc.) from the component to the fully integrated system. Computer-aided design (CAD), computer-aided engineering (CAE) (e.g. finite element method [FEM]/finite element analysis [FEA], SysML™, etc.), and computer-aided manufacturing (CAM) models shall be prepared and submitted in their agreed to standards and templates. An indentured Product Structure (PS) shall be submitted for each configuration item that graphically depicts the hierarchical structure of parts from the configuration item down to assemblies, subassemblies, and components.

9. **OPR:** Systems Engineering and Integration **(**SE&I)

10. **DM:** Configuration Management Office (CMO)

11. **DISTRIBUTION:** Per Contracting Officer's letter

12. **INITIAL SUBMISSION:** Thirty (30) days prior to Preliminary Design Review (PDR). <u>Parts Marking Plan</u>: 60 days after contract award.

13. **SUBMISSION FREQUENCY:** Four (4) weeks prior to each major review, as part of a Technical Data Package (TDP). In addition, MBx models, along with updated PS, shall be submitted between milestones as requested by the procuring activity for the related configuration items.

14. **REMARKS:** None

15. INTERRELATIONSHIPS:

ASME Y14.41	Digital Product Definition Data Practices
ASME Y14.47	Model Organization Practices
ISO 10303, Parts 233, 239, 242, etc.	Refer to Appendix K

16. DATA PREPARATION INFORMATION:

16.1 SCOPE: The Customer or designated Lead Systems Integrator (LSI) shall develop integrated model sets, assembling the various MBx model sets utilizing the agreed upon standards and formats.

16.2 APPLICABLE ITEMS: None.

16.3 CONTENTS: Refer to section 17.

16.4 FORMAT: Determined by specific program/project/activity.

16.5 MAINTENANCE: Refer to section 17.

17. DATA DELIVERABLES:

17.1 The Supplier shall deliver:

17.1.1 Their integrated MBx models representing Contractor's deliverable end items—system and assembly models identifying changes since prior submittal.

17.1.2 The integrated system DMU assembly model shall be an independent model that combines elements from the installation model and the Contractor's end item models.

17.1.2.1 The integrated system, subsystem, or element top assembly DMU model shall not contain simplified model representations.

17.1.2.2 The integrated system of systems DMU (highest level assembly) model shall use a common skeleton structure definition for placement of major elements and their derivative model representations, i.e. a simplified representation.

17.1.3 Simplified representations of the Contractor's system top assemblies and primary integrated ground support equipment (GSE) with the integrated element, if created.

17.1.3.1 A simplified representation is not a Creo Parametric™ (or other CAD) native simple representation (however, these may be created from a simple representation) but is an accurate single surface, water-tight contiguous body representing the nominal "as-designed" configuration or structure.

17.1.3.2 A simplified representation used for space and weight shall determine weight and center of gravity (cg), either as computed or assigned.

17.1.3.3 Keep-out zones and other volume simulators shall be separate models located per the common skeleton structure.

17.1.4 A light-weight viewable derived from the integrated top assembly model set.

17.1.4.1 A light-weight viewable is a CAD-derived product that is used to view CAD graphical data with a standard personal computer and Web downloadable software. Light-weight viewables can be used by those with little or no CAD experience and/or without access to CAD software/licenses. Light-weight viewable files shall contain approximate (faceted) data, exact boundary representation surfaces (non-uniform rational basis spline [NURBS]), product and limited part manufacturing information (PMI), and metadata.

17.1.4.2 Light-weight viewables shall be delivered in formats such as 3D portable document format (PDF) and/or Jupiter Tessellation (JT) in addition to the native 3D CAD.

17.2 All associated models used in the assembly model.

17.3 Creo Parametric™-driven drawings and drawing files of the design/modifications suitable for a construction fabricator.

18. Subsystem model assemblies (i.e. fluid panels, enclosures, umbilicals, etc.) will be provided to the architect and engineer (A&E).

19. The A&E shall deliver:

19.1 Modified assemblies in the same format as they were received.

19.2 Simplified representation of the base structure, tower levels, and primary integrated GSE with the integrated mobile launcher assembly, if created.

19.2.1 A simplified representation is not a Creo Parametric™ simple representation (however, it may be created from a simple representation) but is an accurate single surface, water-tight contiguous body representing the nominal “as-designed” configuration or structure.

19.2.2 A simplified representation used for space and weight shall determine weight and cg, either as computed or assigned.

19.2.3 Keep-out zones and other volume simulators shall be separate models located per the common skeleton structure.

19.3 A light-weight viewable derived from the integrated mobile launcher assembly model.

19.3.1 A light-weight viewable is a CAD-derived product that is used to view CAD graphical data with a standard personal computer and Web downloadable software (e.g. 3Di format derived from the 3D native models (specify type, i.e. JT ISO 14306, Industrial automation systems and integration -- JT file format specification for 3D visualization; 3D PDF, ISO 32000-1, Document management – Portable document format – Part 1: PDF 1.7; etc. Light-weight viewables can be used by those with little or no CAD experience and/or without access to CAD software/licenses.

19.4 An interface detail product (IDP).

19.4.1 By definition, the IDP contains only the CAD files necessary to construct the interface control document (ICD) views. The IDP CAD dataset should be located in vehicle or element coordinates.

19.4.2 An ICD should be as generic as possible. To the extent possible, an IDP should not reflect “background detail” that is subject to change.

19.5 Provide a reference document detailing any name changes (i.e. “WAS”, “IS”) if necessary.

A.5 CONFIGURATION AND DATA MANAGEMENT PROCESS AUDIT (CDMPA)

DATA REQUIREMENTS DESCRIPTION (DRD)

1. DPD NO.: XXX **2. DPD STATUS:** Draft **3. DRD NO.: STD-CDMPA**
4. DATA TYPE: 3 **5. DATE REVISED**:
6. PAGE: 1/2

7. TITLE: Configuration and Data Management Process Audit (CDMPA)

8. DESCRIPTION/USE: To ensure that the Supplier's organization is compliant with the configuration management (CM) requirements of the contract and that the configuration baselines are correctly defined, controlled, accounted for, and verified, and any required corrective actions resulting from the audit are implemented.

9. OPR: [Enter Agency organization with technical responsibility for the supported data.]

10. DM: [Enter Agency organization acquiring the data for a specific program/project/activity.]

11. DISTRIBUTION: Per Contracting Officer's letter.

12. INITIAL SUBMISSION: Per program/project/activity in contract; otherwise, within thirty (30) days of Supplier's Configuration and Data Management Plan (DRD No. STD-CDMP) delivery.

13. SUBMISSION FREQUENCY: Per NASA/Supplier jointly approved audit plan.

14. REMARKS: None

15. INTERRELATIONSHIP: None

16. DATA PREPARATION INFORMATION:

16.1 <u>SCOPE</u>: The CDMPA will ensure that the audited organization is compliant with the Configuration and Data Management (CDM) requirements of the project.

16.2 <u>APPLICABLE ITEMS</u>:
Program/Project/Activity-specific CDM Process Audit Plan

16.3 <u>CONTENTS</u>: The CDMPA is a joint NASA/Supplier activity that is conducted to verify the adequacy of the Supplier's implementation and execution of CDM requirements and identify areas that need correction or improvements. The Supplier shall provide data to support the CDMPA as defined in the Program/Project/Activity-specific Audit Plan, including the following:

a. Configuration and Data Management Plan.
b. Configuration Status Accounting Reports.
c. Deviation and Waiver Approval Requests.
d. Engineering Models, Drawings, and Associated Lists.
e. Engineering/Project Change Proposals.
f. Release Records.
g. Manufacturing Records (including WADs, NCs, Open Work items, etc.).
h. Acceptance Data Package Documentation.
i. Functional Configuration Audit/Physical Configuration Audit (FCA/PCA) Review Findings.
j. Agenda.
k. Presentation Charts.
l. Supplier Self-Assessment Results.
m. Minutes.
n. Findings (Generated at Reviews).
o. Follow-up Closure Status.

16.4 <u>FORMAT</u>: NASA-approved supplier format is acceptable.

16.5 <u>MAINTENANCE</u>: Discrepancies found during the audit shall be documented as Findings Observations, or equivalent, and corrective action assigned for each finding.

A.6 CONFIGURATION AND DATA MANAGEMENT PLAN (CDMP)

DATA REQUIREMENTS DESCRIPTION (DRD)

1. **DPD NO.**: XXX 2. **DPD STATUS:** Draft 3. **DRD NO.: STD-CDMP**
4. **DATA TYPE:** 1 5. **DATE REVISED:**
6. **PAGE:** 1/4

7. **TITLE:** Configuration and Data Management Plan (CDMP)

8. **DESCRIPTION/USE:** To describe the approach for accomplishing how the Supplier shall implement configuration and data management requirements into plans, processes, and procedures in compliance with the overall Agency, program, and project's requirements, policies, and procedures and address configuration and data management planning and organization, configuration identification, configuration control and interface management, configuration status accounting, and configuration verification and audits along with their correlating data access controls/security, etc.

9. **OPR:** NASA Configuration Management Office (CMO) or their Representative

10. **DM:** NASA Data Management Office (DMO) or their Representative

11. **DISTRIBUTION:** Per Contracting Officer's letter

12. **INITIAL SUBMISSION:** Submit ninety (90) days post contract award.

13. **SUBMISSION FREQUENCY:** Submit annual updates as well as necessary submittals due to contract changes.

14. **REMARKS:** None

15. **INTERRELATIONSHIP:** All related configuration and data management (CDM) scope and DRDs.

16. **DATA PREPARATION INFORMATION:**

16.1 **SCOPE:** The CDMP will identify how the Supplier will implement CDM to provide consistency among the product requirements, product configuration information (PCI), and the product throughout the applicable phases of the product life cycle. The CDMP reflects the supplier's planned application of the CDM principles and practices to the Government's identified product context and environment. The CDMP and its sub-tiered policies, processes, and procedures shall define the supplier's entire collective CDM processes and enable CDM Process Audits (e.g. STD-CDMPA).

16.2 APPLICABLE ITEMS:

SAE GEIA-859	Data Management
SAE EIA-649	Configuration Management Standard
SAE EIA-649-2	Configuration Management Requirements for NASA Enterprises

16.3 CONTENTS: The CDMP shall define and explain how the Supplier implements a CDM Program to meet the requirements of GEIA-859, SAE EIA-649, and SAE EIA-649-2, including the following:

16.3.1 Configuration Management Planning and Organization:

16.3.1.1 Purpose and Scope:

16.3.1.1.1 The purpose and objectives shall be stated along with a brief description of the Supplier's management policy and methods as applied to the CDM Program.

16.3.1.1.2 A brief description of the system or system products, including the top-level hardware, software, etc., with lower level component Configuration Items (CIs) for which the supplier is responsible to supply the Government and to which the CDMP pertains.

16.3.1.1.3 Any applicable limitations and assumptions (e.g. time constraints, known risks, customer participation level, resource availability, etc.) that may impact the supplier's ability to perform the defined CDM activities or impact the proposed budget and/or schedule shall be identified.

16.3.1.1.4 The Supplier shall describe the persons, boards, and groups within and external to the Supplier's organization having decisional authority over the planning, implementation, and execution of the CDMP.

16.3.1.1.5 Applicable and reference documents. All specifications, standards, manuals, and other documents, including policy directives, shall be specified in the plan by title, document number, revision, issuing authority, and when applicable, change notice, amendment number, and date of issue. All applicable CDM-related documents (e.g. separate software and sub-supplier CDMPs, risk management plans, etc.) and their interrelationships shall be identified and listed in the plan by title, number, issuing authority, and when applicable, revision, change notice, amendment number, and date of issue.

16.3.1.2 Organization: Describe and graphically illustrate the organizational context within which the planned CDM activities are to be implemented, including:

16.3.1.2.1 All organizations, whether internal or external to the Supplier's organization, that will participate in or are responsible for any CDM activity.

16.3.1.2.2 Responsibility and authority for CDM and all participating groups and organizations, including their roles in Configuration Control Boards (CCBs).

16.3.1.2.3 Description of the Supplier's CDM organization to include how CDM responsibilities are to be allocated and any unique qualifications or training methods and materials required.

16.3.1.2.4 The organizational interface points for both the hardware and the software

products and the interfaces required to implement these relationships.
16.3.1.2.5 The functional integration of CDM activities into other program activities such as technical, management, and design reviews.
16.3.1.3 Configuration Identification:
16.3.1.3.1 List of CIs and computer software configuration items (CSCIs) managed under this CDMP and the criteria for the establishment of CIs and CSCIs.
16.3.1.3.2 Establishment and management of product configuration items (PCIs).
16.3.1.3.3 Establishment of configuration baselines (functional, allocated, and product) and definition of the configuration documentation required for each, including graphic illustration of configuration documentation relationships and describe any other baselines that are required to be tracked by CDM.
16.3.1.3.4 Assignment, application, and control of unique identifiers for each PCI and revisions.
16.3.1.3.5 Identification of release procedures for PCI.
16.3.1.4 Configuration Control and Interface Management:
16.3.1.4.1 Organization, functions, responsibility, and authority of the CCBs.
16.3.1.4.2 Identification of the membership roles for each authorized CCB.
16.3.1.4.3 Classification of changes and the level of authority for change disposition.
16.3.1.4.4 Identification of procedures for processing different types of changes such as Request for Change, Request for Variance, Field Engineering Changes, modification kit authorization, issuance, and tracking and include processes and responsibilities for receiving, recording, evaluating, distributing, and maintaining changes through implementation and closure.
16.3.1.4.5 Identification of the interrelationship between any Interface Working Groups and the configuration control process.
16.3.1.4.6 Identification of the interrelationship between the nonconformance disposition process and the change management process.
16.3.1.5 Configuration Status Accounting:
16.3.1.5.1 Methods for collecting, recording, processing, maintaining, and safeguarding data necessary to provide the status accounting information via reports and/or database access.
16.3.1.5.2 Description of the content and formation for all configuration accounting reports or information system content as related to the identified data elements including:
16.3.1.5.2.1 Identification of currently approved PCI and configuration identifiers associated with each CI.
16.3.1.5.2.2 Status of request for change from initiation to implementation.
16.3.1.5.2.3 Request for Variance.
16.3.1.5.2.4 Traceability of changes to released document through implementation.
16.3.1.5.2.5 Results of configuration audit; status and disposition of discrepancies.
16.3.1.5.2.6 Effectivity and installation status of approved configuration changes to all CIs at all locations.
16.3.1.5.2.7 Methods of access to information in status accounting systems and/or

frequency of reporting and distribution.

16.3.1.6 Configuration Verification and Audits:

16.3.1.6.1 Plans, procedures, documentation, and schedules for functional and physical configuration audits.

16.3.1.6.2 Plans, procedures, documentation, and schedules for conducting CDM system audits and reporting results and to define the expectations and responsibilities of organizations in sufficient detail to allow for planning and funding.

16.3.1.6.3 Plans, procedures, and schedules for reviews necessary for the establishment of functional, allocated, and product baselines.

16.3.1.6.4 Description of the format for audit reports and the method for tracking status and disposition of discrepancies.

16.3.1.7 Configuration data management shall describe the methods for meeting the CDM technical data requirements under the computer-aided transmission and distribution requirements for the project. The following lists areas, but not necessarily all of the areas, to be considered when addressing this subject in the CDMP:

16.3.1.7.1 How data deliverables, including CDM identification data and changes, are delivered, verified, stored, and maintained.

16.3.1.7.2 How data is processed and the type of records, hardcopy or digital.

16.3.1.7.3 How sensitive but unclassified (SBU) and limited rights information is protected.

16.3.1.7.4 Method of notification/acknowledgement of receipt, return, or acceptance.

16.3.1.7.5 Indication of time constraints, if any, or automatic data acceptance.

16.3.1.7.6 Data status accounting.

16.3.1.7.7 How data is accessed.

16.3.1.7.8 Methods of indicating acceptance, provisional acceptance, approval, or rejection, as applicable.

16.3.1.8 Records: Identify and maintain CDM-related records.

16.4 **FORMAT**: CDMP template available from the Government; supplier format accepted upon approval by the Government.

16.5 **MAINTENANCE**: Changes shall be incorporated by complete revision/reissue and submitted at least annually.

A.7 CONFIGURATION STATUS ACCOUNTING (CSA)

DATA REQUIREMENTS DESCRIPTION (DRD)

1.	**DPD NO.**: XXX	2.	**DPD STATUS**: Draft	3.	**DRD NO.**: **STD-CSA**
4.	**DATA TYPE: 3**			5.	**DATE REVISED:**
				6.	**PAGE: 1/3**

7. **TITLE**: Configuration Status Accounting (CSA)

8. **DESCRIPTION/USE**: To provide accurate and timely information concerning a product and its product configuration information throughout the product life cycle.

9. **OPR**: Configuration Management Office (CMO)

10. **DM**: [Enter Agency organization acquiring the data for a specific program/project/activity.]

11. **DISTRIBUTION**: Per Contracting Officer's letter

12. **INITIAL SUBMISSION**: Three (3) weeks prior to Preliminary Design Review (PDR)

13. **SUBMISSION FREQUENCY**: At major design reviews and configuration audits, and as requested

14. **REMARKS**: None

15. **INTERRELATIONSHIP**:
DRD No. STD-CDMP

16. **DATA PREPARATION INFORMATION**:

16.1 **SCOPE**: The CSA will provide a status of configuration baseline changes and recording of accurate and timely product configuration information that will be captured as it is created over the product life cycle.

16.2 **APPLICABLE ITEMS:**

SAE EIA-649	Configuration Management Standard
SAE EIA-649-2	Configuration Management Requirements for NASA Enterprises

16.3 **CONTENTS:** The CSA shall meet the requirements of SAE EIA-649 and SAE EIA-649-2. The supplier shall provide the following reports as required by the contract:

a. Dispositioned Change Activity Report shall list all proposed changes, including variances that have been received and Customer disposition action, arranged in a change proposal number sequence. The following data elements shall be included:
   (1) Identification of the change proposal, including the basic number, revision level, title, and associated change package number.
   (2) Identification of the configuration item (CI) affected, including the number, nomenclature, and CI effectivity by serial number(s).
   (3) Identification of contractual change authorization, including number and date.
   (4) Disposition of the change proposal, i.e. "Approved", "Approved with Changes", or "Disapproved".
   (5) Identification and date of Supplier's internal authorization documentation.

b. Pending Change Activity Report shall list all change requests that are pending, either for internal Supplier approval or Customer approval, and shall be arranged in a change proposal number sequence. The following data elements shall be included:
   (1) Identification of the change action, including the basic number, revision level, title, and associated change package number.
   (2) Identification of the CI affected, including number, nomenclature, and CI effectivity by serial number(s).
   (3) Depending on the processing status, enter the actual or estimated date of submittal to the Customer.

c. Configuration Identification Report shall identify the baseline configuration and all configuration change actions for each CI. Hardware and software changes shall be listed separately from Variance Request (VR) actions. The following data elements shall be included:
   (1) Contract and Contractor identification.
   (2) CI identification, including, as appropriate, CI number and nomenclature, part number, and specification number.
   (3) Configuration change data, including the following:
      A. Change proposal identification, including type of action (e.g. Change Request [CR] or VR), number, title, and associated change package number (if applicable).
      B. Change application, including item(s) affected (e.g. hardware, software, or documentation), first and total effectivities, and the incorporation or installation points.
      C. Change disposition, including the identification of contractual change authorization.

d. Change Incorporation Status Report shall list the status of CR incorporation into CIs and shall be organized by CI number. The following data elements shall be included:
   (1) CI identification number and serial number.
   (2) CR number, title, type of change, and associated change package number.
   (3) Change effectivity, engineering release date, and incorporation point.
   (4) In-line incorporation completion date, scheduled and actual, as appropriate.

(5) Mod Kit data shall include identification, authorization, effectivity, man-hour estimates and status, installation location, shipping date (scheduled and actual), and completion date(s) for installation and retest, if required.

e. As-designed/As-built Comparison Report describes the differences between the as-designed and as-built configurations.

f. Software CSA Reports shall provide reports as follows:

(1) Released documentation, including specifications and interface information.

(2) Problem reporting, deviation/waiver activity, including dispositions and open actions.

(3) Promotion tracking of code for each file through development, testing, validation/verification, and operational deployment.

(4) Build records and version control – provide data for the Version Description Document (VDD).

16.4 FORMAT: Supplier format is acceptable provided the requirements of SAE EIA-649-2 are addressed for each report.

16.5 MAINTENANCE: None required

A.8 SPECIFICATION AND DRAWING TREES (SDT)

DATA REQUIREMENTS DESCRIPTION (DRD)

1. DPD NO.: XXX **2. DPD STATUS**: Draft **3. DRD NO.: STD-SDT**
4. DATA TYPE: 3 **5. DATE REVISED:**
6. PAGE: 1/2

7. TITLE: Specification and Drawing Trees (SDT)

8. DESCRIPTION/USE: A specification tree is a generation breakdown of the specifications with interrelationships, as applicable, to the configuration items. A drawing tree is a generation breakdown of the engineering drawings that depicts the allocation of requirements of the configuration item specification.

9. OPR: [Enter Agency organization with technical responsibility for the supported data.]

10. DM: [Enter Agency organization acquiring the data for a specific program/project/activity.]

11. DISTRIBUTION: Per Contracting Officer's letter

12. INITIAL SUBMISSION: Specification trees - Three (3) weeks prior to Preliminary Design Review (PDR). Drawing trees - Three (3) weeks prior to Critical Design Review (CDR).

13. SUBMISSION FREQUENCY: Specification tree updated for CDR; specification and drawing trees updated for the Physical Configuration Audits (PCA).

14. REMARKS: None

15. INTERRELATIONSHIP: None

16. DATA PREPARATION INFORMATION:

16.1 SCOPE: SDTs depict the hardware and software configuration items in top down, or generation breakdown, form.

16.2 APPLICABLE ITEMS: None

16.3 CONTENTS: The SDTs shall consist of an indentured or generation breakdown listing of all specifications or drawings applicable to a configuration item or items.

16.4 FORMAT: Contractor format is acceptable upon Government approval.

16.5 MAINTENANCE: Changes shall be incorporated by complete reissue.

NOTE to STD-SDT

Sample Statement of Work Words:

Specification and Drawing Trees. Specification and drawing trees shall be provided in accordance with DRD No. STD-SDT.

NOTE:
These instructions on DRD applicability are not a part of the DRD and should not be included in a DPD.

A.9 ENGINEERING MODELS, DRAWINGS, AND ASSOCIATED LISTS (EMDAL)

DATA REQUIREMENTS DESCRIPTION (DRD)

1. DPD NO.: XXX **2. DPD STATUS**: Draft **3. DRD NO.**: **STD/EMDAL**
4. DATA TYPE: **3** **5. DATE REVISED**:
6. PAGE: 1/4

7. TITLE: Engineering Models, Drawings, and Associated Lists (EMDAL)

8. DESCRIPTION/USE: To provide engineering data defining the design to the extent required to support manufacturing, test, and logistics support of the vehicle and payload systems and required spare parts. EMDALs shall be sufficient to depict the detailed configuration of all system, subsystem, and component levels and to include ground support equipment (GSE), electrical ground support equipment (EGSE), and ancillary support equipment (ASE). Two (2)D and 3D computer-aided design (CAD) models shall be submitted as primary information. A Product Breakdown Structure and drawing tree shall be submitted for each configuration item that graphically depicts the hierarchical structure of all parts (components, assemblies, etc.) from the top-level configuration item down to assemblies, subassemblies, and components.

9. OPR: NASA Configuration Management Office (CMO) or their Representative

10. DM: NASA Data Management Office (DMO) or their Representative

11. DISTRIBUTION: Per Contracting Officer's letter

12. INITIAL SUBMISSION: Three (3) weeks prior to Preliminary Design Review (PDR).

13. SUBMISSION FREQUENCY: Three (3) weeks prior to each major review, as part of a Technical Data Package (TDP), and as requested. In addition, 3D CAD models shall be submitted between milestones as requested by the procuring activity; and updated Product Structure and/or Drawing Trees shall be submitted for the related configuration items' Physical Configuration Audit (PCA).

14. REMARKS:

15. INTERRELATIONSHIP:
DRD-TDP
DRD-MRI

16. DATA PREPARATION INFORMATION:

16.1 **SCOPE:** EMDALs disclose (directly or by reference) the physical and functional requirements of an item by means of graphics or textual presentation or combinations of both, as implemented by 3D models. Product Structure Reports and Drawing Trees depict the hardware and software configuration items in graphic, top down, hierarchical structures.

16.2 **APPLICABLE ITEMS:**

	Global Drawing Requirements Manual (GDRM) (Tenth Edition)
ASME Y14.5	Dimensioning and Tolerancing
ASME Y14.100	Engineering Drawing Practices
ASME Y14.24	Types and Applications of Engineering Drawings
ASME Y14.34	Associated Lists
ASME Y14.41	Digital Product Definition Data Practices
ASME Y14.47	Model Organization Practices
MIL-STD-130	Department of Defense Standard Practices, Identification Marking of U.S. Military Property

16.3 **CONTENTS:** EMDAL requirements shall include:

16.3.1 Part I – Engineering models, drawings, analyses, and associated lists shall meet the requirements of ASME Y14.100. Geometric dimensioning and tolerancing shall be implemented in accordance with ASME Y14.5. Supplemental 2D/3D CAD shall meet the requirements of ASME Y14.41 and ASME Y14.47. EMDALs of end items, elements, and/or all components and assemblies shall be provided to define the details necessary for the manufacture, test, inspection, operations, and logistic support of the system. This definition shall:

a. Reflect the end-product at its current level of design maturity.
b. Provide the engineering data for logistics support products.
c. Provide the necessary data to permit manufacture and/or acquisition of items identical to the original item(s).

16.3.2 Document directly or by reference the following:

a. Details of unique processes (i.e. not published or generally available to industry) when essential to design and manufacture.
b. Performance ratings.
c. Dimensional and tolerance data (geometric dimensioning and tolerancing [GD&T] for all external and major internal interfaces shall have GD&T applied.)
d. Critical manufacturing processes and assembly sequences, and rigging procedures.
e. Diagrams.
f. Mechanical and electrical connections.
g. Physical characteristics, including form and finish.
h. Details of material identification, including heat treatment and protective coatings.
i. Inspection, test, and evaluation criteria.

j. Equipment calibration requirements.
k. Quality assurance requirements.
l. Hardware marking requirements.
m. Requirements for reliability, maintainability, environmental conditions, shock, vibration testing, and other operational or functional tests.

16.3.3 Limited rights-in-data items - Engineering data for items that the Government does not have unlimited rights in data shall specify the form, fit, and function requirements of the item and conform to the requirements for a control drawing as defined in ASME Y14.100 or a specification prepared in accordance with project requirements.

16.3.4 Part II - Cable interconnect diagrams (CIDs), electrical system schematics, cable harness assembly models/drawings, and wiring lists. Cable interconnect diagrams, electrical system schematics, cable harness assembly models/drawings, wiring lists, and fluid system schematics shall be prepared in accordance with ASME Y14.100. Part I models/drawings shall be utilized to the maximum extent possible in providing the design definition. The models/drawings shall include the following:

a. Cable interconnect diagrams shall show graphically the arrangement of external electrical cabling that interconnects electrical assemblies and/or equipment. The CID shall show all cable runs and terminations; each cable shall be identified by reference designation number. The connector short sign shall be identified.
b. Electrical system schematics shall illustrate and describe circuit items with symbols placed such that a circuit may be traced from item to item in the sequence of its function. The placement and arrangement of these circuits shall follow a logical sequence of presentation to provide a clear description of the distribution.
c. Cable harness assembly models/drawings shall meet the requirements of Global Drawing Requirements Manual (10th edition) and ASME Y14.24**.**
d. Component Level Documentation - Schematics and/or wiring lists for components, including interconnecting cable harnesses, shall be provided.
e. Overall Grounding Documentation - The grounding schematic shall show the details of all grounds and power returns from source to loads. All connections shall be shown. It shall also show details of all EGSE interconnections to facility and safety grounds. Grounding schematics shall meet the requirements of Global Drawing Requirements Manual (10th Edition).
f. The fluid system schematic shall illustrate and describe all components with symbols and flow designators such that the fluid system may be traced from component to component (such as pumps, valves, meters, regulators, and filters). The schematics shall document the range requirements (flow, temperature, and pressure) for all component external interfaces and line sizes. The placement and arrangement of these components shall follow a logical sequence of presentation to provide a clear description of the flow of fluids in the system. The schematics shall reference EMDALs for configuration details.
g. Engineering models/drawings shall specify marking criteria and methods for identification of parts produced or procured. Markings shall be compliant with MIL-

STD-130 with compliant unique identification marking (UID)/item unique identification (IUID) 2D codes. All parts shall be physically marked. When physical marking or tagging causes a deleterious effect, labels, tags, and nameplates may be considered. MIL-STD-130 shall be used for paper labels, tagging, and nameplates.

h. A Product Breakdown Structure and drawing tree shall be submitted for each configuration item that graphically depicts the hierarchical structure of drawings/parts from the configuration item down to assemblies, subassemblies, and components.

16.4 **FORMAT**: Format for engineering CAD models shall be in accordance with ASME Y14.41 and ASME Y14.47 and delivered in Government's specified native and neutral formats. Format of engineering drawings shall be in accordance with ASME Y14.100. In addition, formats for electrical engineering drawings shall be in accordance with Global Drawing Requirements Manual (10th Edition). All drawings shall be delivered in native CAD, machine-readable portable document format (PDF), and agreed to neutral formats. Additionally, any native file formats used to create the PDF drawings shall be delivered (e.g., *.VSD or *.DWG). Two (2)D/3D CAD models shall be in accordance with ASME Y14.41/ASME Y.14.47, in the current version of native-developed CAD, fully parametric and associative. Native format and machine-readable PDFs are acceptable for drawing trees. The Contractor shall deliver Creo Parametric™ compatible 3D models of the components. Alternate formats may be acceptable upon negotiation. All documentation/data shall include the Contractor's CAGE code and document numbers. The Contractor may submit electronic files of drawings and CAD models via compact disc (CD), digital versatile disc (DVD), or direct electronic transfer (product data management [PDM] Tool, file transfer protocol [FTP], etc.) as specified by the Government.

16.4.1 For all electronic deliveries, the Contractor shall include a listing of the creating environment to include the following:

a. CAD product name/version/patches.
b. Subordinate (plug-in) software/version/patches.
c. Description of hardware (e.g. minimum/desired requirements for central processing unit (CPU), graphics processing unit (GPU), random access memory (RAM), storage, etc.)
d. Operating system/version/patches.

16.5 **MAINTENANCE**: All documents produced under this DRD shall be maintained current. Changes to and/or updating of engineering models, drawings, associated lists, product structures, and drawing trees shall be in accordance with the Contractor's approved drawing system and the provisions herein. Changes to engineering drawings under the Government's Class I change control shall be submitted by Engineering Change

Proposal. The Contractor shall maintain the capability to restore and modify any engineering data used in the design throughout the project life cycle.

A.10 CHANGE REQUEST (CR)

DATA REQUIREMENTS DESCRIPTION (DRD)

1. **DPD NO.**: XXX 2. **DPD STATUS**: Draft 3. **DRD NO.**: **STD-CR**
4. **DATA TYPE: 1** 5. **DATE REVISED:**
6. **PAGE: 1/2**

7. **TITLE:** Change Request (CR)

8. **DESCRIPTION/USE:** To process and submit proposed engineering changes for evaluation and disposition by the appropriate Configuration Approval Authority.

9. **OPR:** NASA Configuration Management Organization (CMO)

10. **DM:** NASA CMO

11: **DISTRIBUTION:** Per Contract Schedule

12. **INITIAL SUBMISSION:** Per Contract Schedule

13. **SUBMISSION FREQUENCY:** As required

14. **REMARKS:** None

15. **INTERRELATIONSHIP:** None

16. **DATA PREPARATION INFORMATION:**

16.1 **SCOPE:** The Change Request (CR) will document information by which a change is proposed, described, justified, and submitted with impact assessment to the Approval Authority.

16.2 **APPLICABLE ITEMS:**
SAE EIA-649-2, Configuration Management Requirements for NASA Enterprises.

16.3 **CONTENTS:** The CR shall document a proposed engineering change meeting the requirements of SAE EIA-649-2 and contain the following minimum information:

a. CR number,
b. CR revision-version,
c. Creation date,
d. CR title,
e. Change package number,

f. Originator name,
g. Originator company and organization code,
h. Commercial and Government Entity (CAGE) code required for Contractor or external agreement,
i. Contact or agreement number required for Contractor or external agreement,
j. Recommended priority: routine, urgent, or emergency,
k. Change description,
l. Change classification,
m. Change type (hardware, software, or documentation),
n. Impacts (cost, schedule, risk, and technical),
o. Justification or reason for change,
p. Programs and projects affected,
q. Affected baselines, documents, and data,
r. Affected configuration item(s) and effectivity,
s. Modification Kit information (if required),
t. The following information is recommended for inclusion: Related MBx models/data (per DRD No. STD-MBx); schedule need dates; originator's e-mail and telephone; sensitive but unclassified (SBU) restrictions; consequences if not incorporated; Contracting Officer; office of primary responsibility (OPR); owning Center; and authorization to submit/initiate document number.

16.4 FORMAT: Agreed-to supplier format is acceptable as long as it meets the content requirements of paragraph 16.3.

16.5 MAINTENANCE: All requested CR changes require submittal of a CR revision.

A.11 FUNCTIONAL CONFIGURATION AUDIT AND PHYSICAL CONFIGURATION AUDIT (FCA/PCA) DOCUMENTATION (AD)

DATA REQUIREMENTS DESCRIPTION (DRD)

1. DPD NO.: XXX **2. DPD STATUS**: Draft **3. DRD NO.**: **STD-AD**
4. DATA TYPE: 2/3 **5. DATE REVISED:**
6. PAGE: 1/6

7. TITLE: Functional Configuration Audit and Physical Configuration Audit (FCA/PCA) Documentation (AD)

8. DESCRIPTION/USE: To support the Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA). The FCA is an audit to verify performance of the configuration item (CI)/computer software configuration item (CSCI) against approved configuration documentation. The PCA is an audit of the configuration documentation and quality control records to ensure the "as-built" configuration complies with the "as-designed" configuration defined in the documentation.

9. OPR: [Enter Agency organization with technical responsibility for the supported data.]

10. DM: [Enter Agency organization acquiring the data for a specific program/project/activity.]

11. DISTRIBUTION: See Attachment 2.

12. INITIAL SUBMISSION: See Attachment 2.

13. SUBMISSION FREQUENCY: Per configuration audit schedule.

14. REMARKS: NASA will document audit details and schedule and provide it to the Contractor within ninety (90) days post award.

15. INTERRELATIONSHIP: None

16. DATA PREPARATION INFORMATION:

16.1 <u>SCOPE</u>: FCA/PCA documentation contains the required documentation necessary to support the configuration audit for a CI and a CSCI.

16.2 <u>APPLICABLE ITEMS</u>:

SAE/EIA-649-2 Configuration Management Requirements for NASA Enterprises

16.3 **<u>CONTENTS</u>:** Requirements specifications, verification planning documentation, and other required data for the FCA shall be that collected for the CI/CSCI that is to be formally accepted. The PCA verifies that the "as-built" configuration reflects the required characteristics documented in the "as-designed" configuration. Configuration and quality control records and other documents defining the "as-built" or "as-coded" configuration defined in the documentation shall be provided.

SAE/EIA-649-2 provides guidelines on documentation required for the FCA and PCA. See Attachment 1 for documentation required for the audits.

Additional documentation requirements to be provided are:

a. Agenda—The agenda shall specify the date, time, and place for the scheduled audit, specific review items, supporting documentation, and key participants. Submit approved copies at the review. See Attachment 2.
b. Presentation Charts—Presentation charts shall be submitted at the start of the audit. They shall summarize the details contained in the data package and identify compliance with the contract requirements. See Attachment 2 for distribution and availability of data.
c. Plan—A plan shall be submitted prior to initiating the audit stating configuration items to be reviewed, data required to perform the review, how audit action items are recorded and tracked, defining success criteria, and providing for formal approval of the audit. The plan shall also define extent of Contractor and Government participation in the review.
d. Audit Minutes Package—The official Audit Minutes Package (not to be confused with the daily audit minutes) shall contain a description of the audit with sufficient detail to enable the audit to be made a matter of record. The Audit Minutes Package shall include the presentation charts, a listing of Findings, audit action items identified with actionee and suspense data, approved FCA/PCA certification sheets, any daily audit minutes, and any record of other findings, conclusions, and recommendations as applicable. See Attachment 2 for distribution and availability of data.
e. Findings—The findings shall show audit action items identified with actionees, suspense dates, and closure status shall be submitted. See Attachment 2 for distribution and availability of data.

16.4 **<u>FORMAT</u>:** NASA-approved Contractor format is acceptable.

16.5 **<u>MAINTENANCE</u>:** As required to correct errors and to maintain findings closure status.

ATTACHMENT 1
CONFIGURATION AUDIT REQUIRED DATA

<u>Documentation required for the FCA</u> (As Applicable)

- Requirement Specifications (including ICDs).
- Drawings and parts list.
- List of approved Drawing Engineering Orders (EOs).
- Verification Compliance Report (VCR) (provides traceability for all requirements to associated verification objectives/requirements and to evidence of compliance).
- Approved Change Requests (CRs) and Variance Requests (VRs) (i.e. deviations/waivers) incorporated and pending.
- An account of Change Requests (CRs) incorporated and tested as well as proposed.
- Specification and drawing tree.
- Materials Usage Agreement (MUAs).
- Material Identification Usage List (MIUL).
- Certification of Qualification(s) (COQ).
- Qualification Test Deficiencies List
- Verification requirements and procedures.
- Software (CSCI)-specific data:
  - Software verification data.
  - Records that reflect the changes made to design release configuration for the CSCI.
  - Software Version Description Document (VDD).
  - Findings of all internal CDM and software (including field-programmable gate array (FPGA) devices that contain software that runs executable code) QA audits of the CSCI.
  - List of FPGA devices that contain software that runs executable code.
- Critical Design Review (CDR) review item discrepancies (RIDs) and dispositions.
- Hazard Reports (HR) and HR open issues.
- Failure Mode Effects Analysis (FMEA) and FMEA open issues.
- List of open issues for internal or external interfaces.
- Test plans and procedures.
- Test reports.
- ALERTS tracking log.

<u>Documentation required for the PCA</u> (As Applicable)

- Acceptance Data Package (ADP)
- Final version of all requirement specifications (including ICDs).
- Configuration Status Accounting (CSA) reports as requested at the audit.
- Software (CSCI)-specific data:
  - Final version of all software operating and support manuals.
  - Final version of software Version Description Document (VDD).
  - Software release and build records.
- All FCA findings (audit action items) for each CI/CSCI (i.e. official Audit Minutes Package).
- List of approved and outstanding CRs and VRs.
- All approved contract Directives.
- Copies of CRs and VRs as requested at the audit.
- Data defining “as-designed” configuration:
  - Drawing and specification tree.
  - Product drawings and parts list as requested at the audit.
  - Indentured Parts List (IPL).
  - Lists of all outstanding EOs that have been incorporated into the CI (and are awaiting incorporation into information).
- Acceptance Test Procedures (ATPs) and associated ATP Report (test results).
- As-run test procedures (when applicable, include any test discrepancy records).
- Identification of all changes made during test.
- Identification of any approved and required changes not completed.
- Copy of parts tags or verification closure for verification items verified by inspection method.
- Data defining “as-built” configuration:
  - As-Built Configuration List (ABCL).
  - Manufacturing and inspection (build) records as requested at the audit.
- Discrepancy Reports (DR's).
- Summary and Status of Open Materials Review Board (MRB) actions (including list of open MRB Actions).

Continued

ATTACHMENT 1 (Continued)
CONFIGURATION AUDIT REQUIRED DATA

<u>Documentation required for the PCA</u> (As Applicable)

- Proposed DD Form 250, Material Inspection and Receiving Report (for transfer from external Supplier to NASA).
- DD Form 1149, Requisition and Invoice/Shipping Document (for Government-to-Government transfer).
- Complete shortage list.
- ALERTS tracking log.

NOTE: This list may require tailoring for a specific contract and its deliverables. Examples would be supplementation with MBx models/data sets, deletion of software requirements if no software was required per the contract.

ATTACHMENT 2

FCA/PCA DOCUMENTATION DISTRIBUTION AND AVAILABILITY OF DATA

Document	Data Type	FCA Copies/Availability	PCA Copies/Availability
Agenda	2	One/15 days prior to audit/approved copies at audit	One/15 days prior to audit/approved copies at audit
Data Package	3	One/Two weeks prior to audit	One /Two weeks prior to audit
Presentation Charts	3	One for each attendee at audit	One for each attendee at audit
Audit Minutes Package	2	One at audit/copy to each attendee within two weeks	One at audit/one to each attendee within two weeks
Findings (generated at Reviews)	2	Provided as hard copy or electronically per the project-specific Audit Plan.	Close out to be as specified in the project-specific Audit Plan.

NOTE: This list may require tailoring for a specific contract and its deliverables.

NOTE to STD-AD

Functional Configuration Audit and Physical Configuration Audit (FCA/PCA) Documentation

Sample Statement of Work Words (*See SOW Tailoring Note below.)

Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA): FCA/PCA shall be conducted in accordance with the requirements specified in SAE/EIA-649-2. The data required to support the FCA and PCA shall be provided as defined in DRD No. STD-AD.

The Contractor shall provide the facilities and administrative support necessary for the audits. The requirements for the necessary support are defined in SAE/EIA-649-2 and as follows: (1) provide support for maintaining a system for recording, processing, tracking, and reporting the status of all findings (FCA/PCA Action Items) identified during the audit, corrective action, and closeout status; and (2) provide facilities and administrative support to the audit team(s).

***SOW Tailoring Note**

Tailoring of SOW Words to Include Contractor Self-assessment FCA/PCA: (Although the Government normally conducts and approves the FCA/PCA, it may be beneficial to the Government to limit personnel involvement in the detailed reviews and delegate to the Contractor additional responsibility for the conduct of the FCA/PCA on a project-by-project basis. It is incumbent upon the NASA Project Manager and the Project CDM representative to assure that the project-specific additional responsibility is tailored into the SOW and that DRD No. STD-AD is tailored to reflect the additional documentation to be supplied.)

Application Data: FCA/PCA audits certify that configuration items (CIs/CSCIs) meet criteria for establishing the *Product Baseline* as defined in SAE/EIA-649-2. The FCA/PCA may be included within the scope of the Systems Acceptance Review so long as specific FCA/PCA certifications are obtained.

***Sample complete CDM SOW ***

NOTE:
The applicability/tailoring instructions on this DRD are not a part of the DRD and should not be included in a DPD.

A.12 REQUIREMENTS EXCHANGE FORMAT (REF)

DATA REQUIREMENTS DESCRIPTION (DRD)

1. **DPD NO.**: XXX 2. **DPD STATUS**: Draft 3. **DRD NO.**: **STD-REF**
4. **DATA TYPE: 2/3** 5. **DATE REVISED:**
6. **PAGE: 1/13**

7. **TITLE:** Requirements Exchange Format (REF)

8. **DESCRIPTION/USE:** To facilitate digital integration and interoperability of requirements by defining deliverables (content, format, etc.) for requirement objects enabling the exchange between stakeholders during the full systems' life cycle. Data delivered from a Requirements Management (RM) System or exchanged between disparate RM systems shall share the following minimum set of requirement attributes for integration purposes. This DRD contains the format and content preparation instructions for Requirement Objects and should be tailored for given contract. RIF/ReqIF™ (Requirements Interchange Format) is an XML file format that can be used to exchange requirements, along with their associated metadata, between software tools from different vendors. This requirements exchange format and DRD also define a workflow for transmitting the status of requirements between supplier chains.

9. **OPR:** NASA Systems Engineering and Integration (SE&I)

10. **DM:** NASA Configuration Management Office

11: **DISTRIBUTION:** TBD

12. **INITIAL SUBMISSION:** Within thirty (30) days of contract award

13. **SUBMISSION FREQUENCY:** Thirty (30) days prior to each Contract Major Milestone. Interim submittals shall be made available per request up to 60 days prior to a scheduled delivery.

14. **REMARKS:** NASA will provide draft delivery schedule and interim requests through the Contracting Officer's Representative to the contractor within sixty (60) days of contract award.

15. **INTERRELATIONSHIP:** None

16. **DATA PREPARATION INFORMATION:**

16.1 **SCOPE:** Supplier shall deliver requirement data sets necessary to support the building of an integrated requirement set representing the program's top level end items representing the integrated system.

16.2 **APPLICABLE ITEMS:**

SAE/EIA-649-2	Configuration Management Requirements for NASA Enterprises
RIF/ReqIF™	Requirements Interchange Format
ISO 10303-233	Part 233: Application protocol: Systems engineering
ISO/TS 10303-1348	Requirement management

16.3 **CONTENTS:** The following items provide a technical description of the items necessary for supporting an acquisition, production, engineering, and logistics support (e.g. requirements data for the entire life cycle [initial design through retirement]).

16.3.1 Technical Data Package shall include one or more of the following:

UUID—**U**niversally **U**nique **ID**entifier is a 16-octet (128-bit) number. In its canonical form, a UUID is represented by 32 hexadecimal digits, displayed in five groups separated by hyphens, in the form 8-4-4-4-12 for a total of 36 characters (32 alphanumeric characters and four hyphens). (Source: In accordance with ISO/IEC 11578:1996, Information Technology – Open Systems Interconnection – Remote Procedure Call [RPC])

For example: **550e8400-e29b-41d4-a716-446655440000**

Datetime**—**The combination of a date and a time. Its value space is described as a combination of date and time of day in Chapter 5.4 of ISO 8601. Its lexical space is the extended format:

[-]CCYY-MM-DDThh:mm:ss[Z|(+|-)hh:mm]

The time zone may be specified as Z(UTC) or (+|-)hh:mm. Time zones that are not specified are considered undetermined.

For example: 2013-04-25T23:54:32.000Z

Object Type = REQUIREMENT

A requirement is defined as the agreed upon need, desire, want, capability, capacity, or demand for personnel, equipment, facilities, or other resources or services by specified quantities for specific periods of time or at a specified time expressed as a "shall" statement. Acceptable form for a requirement statement is individually clear, correct, feasible to obtain, unambiguous in meaning, and can be validated at the level of the system structure at which stated. In pairs of requirement statements or as a set, collectively, they are not redundant, are adequately related with respect to terms used, and are not in conflict with one another.

Required attributes

Requirement ID number—A system identifier assigned by the owning RM system which is unique to the owning RM system.

Property type = fixed-string
Cardinality = single
Max length = 60 characters

Requirement UUID—Universally Unique Identifier (see above)

Property type = UUID
Cardinality = single
Max length = 36 characters (32 alphanumeric characters and four hyphens)

Requirement Name—Short text/title of the requirement object.

Property type = string
Cardinality = single
Max length = unlimited *

Requirement Text (Description)—The "shall" statement defining the specific requirement.

Property type = string
Cardinality = single
Max length = unlimited *

Lifecycle Status/State—Life-cycle status or state of the requirement.

Legal values =
- **In-Work** - Initial stage of an item that has not been through any review process
- **Completed** - Item that has been reviewed and approved but has not been baselined
- **Accepted** - Item that has been reviewed and approved by a panel/board and is ready for baseline

Obsolete – Item that has been overcome by events, canceled, or deleted, and is no longer valid.

Property type = string
Cardinality = single

Previous Version UUID—The UUID of the previous version of the specified requirement. If no previous version exists, use the current version UUID.

Property type = UUID
Cardinality = single
Max length = 36 characters (32 alphanumeric characters and four hyphens)

Last Modified Date—The date this object was last modified.

Property type = datetime
Cardinality = single

System Id—The identification of the sender/source system that is unique and constant throughout the life of system. The Digital Collaborative Environment **(**DCE) assigned string with input from system owner.

Property type = constant unique string
Cardinality = single
Max length = 36 characters

Optional Attributes – *(include as applicable)*

Requirement Type—The initial classification of a requirement that is mandatory for correct requirements definition and relationship definition

Constraint—**Requirement associated with a limitation or implied requirement that constrains the design solution or implementation of the systems engineering process, is not changeable by the enterprise

Functional—**Requirement associated with identifying, describing, and relating the functions a system must perform to fulfill its goals and objectives

Interface—**Requirement associated with identifying, describing, and relating the functions a system must perform to fulfill its goals and objectives

Performance—**How well these functions must be performed (used in terms of quantity, quality, coverage, timeliness, or readiness), along with the conditions under which the function is performed

Physical—A requirement that specifies a physical characteristic that a system or system component must possess.

TPM (Technical Performance Measure)—The identification, prediction, measurement, and demonstration of the achievement of key technical objectives that reflect the ability of the system design to satisfy the system effectiveness objectives.

Verification—Requirements that specify the verification events needed to prove the satisfaction of the product requirements and help to define the verification process and environment

Operational**—Requirements associated with identifying, describing, and relating the operations of a system must perform to fulfill Mission Objectives

Maintenance—Requirements that define the actions necessary for retaining an item in or restoring it to a specific condition

Property type = string
Cardinality = single

Rationale—Contains Rationale of why and what of the internal and external requirement. Intended to clarify or give additional information that may be needed for the user to better understand the scope of the requirement

Property type = string
Cardinality = single
Max length = unlimited *

Comment—Additional text about the object

Property type = string
Cardinality = single
Max length = unlimited *

Upstream UUID—The UUID of the requirement from which this requirement was derived. This information will allow for validation of traceability

Property type = UUID
Cardinality = multi

Downstream UUID—The UUID of the requirement(s) that are derived from this requirement (the "children" of this "parent")

Property type = UUID
Cardinality = multi

Verification Method – The method by which this requirement will be verified

Legal values =

Test - the verification of a product or system using a controlled and predefined series of inputs, data, or stimuli to ensure that the product or system will produce a very specific and predefined output as specified by the requirements.

Demonstration - the manipulation of the product or system as it is intended to be used to verify that the results are as planned or expected.

Inspection - the nondestructive examination of a product or system using one or more of the five senses (visual, auditory, olfactory, tactile, taste). It may include simple physical manipulation and measurements

Analysis - the verification of a product or system using models, calculations, and testing equipment. Analysis allows predictive statements to be made about the typical performance of a product or system based on the confirmed test results of a sample set or by combining the outcome of individual tests to conclude something new about the product or system. It is often used to predict the breaking point or failure of a product or system by using nondestructive tests to extrapolate the failure point.

Property type = string
Cardinality = multi

** As defined by the NASA Data Architecture Framework (NDAF).

Object type = REQUIREMENT SPECIFICATION

Required attributes

Specification UUID—UUID of the specification

Property type = UUID
Cardinality = single

Specification Name—Short text/title of the specification object

Property type = string
Cardinality = single
Max length = unlimited *

Specification number—A system identifier assigned by the owning RM system which is unique to the owning RM system

Property type = fixed-string
Cardinality = single
Max length = 60 characters

Lifecycle Status/State—Life-cycle status or state of the specification

Legal values =
In-Work - Initial stage of an item that has not been through any review process
Completed - Item that has been reviewed and approved but has not been baselined
Accepted - Item that has been reviewed and approved by a panel/board and is ready for baseline
Obsolete – Item that has been overcome by events, canceled or deleted, and is no longer valid.

Property type = string
Cardinality = single

Specification Description—A description of the requirement specification

Property type = string
Cardinality = single
Max length = unlimited *

Specification Effectivity—Defines the applicability of a specific revision of a specification to specific end item(s) (i.e. to which specific hardware or software item instance does this specification apply?)

Property type = string
Cardinality = multi
Max length = unlimited *

Optional Attributes

Upstream UUID—The UUID of the requirement specification from which this specification was derived. This information will allow for validation of traceability.

Property type = UUID
Cardinality = multi

Downstream UUID—The UUID of the requirement specifications that are derived from this specification (the "children" of this "parent")

Property type = UUID
Cardinality = multi

Previous Version UUID—The UUID of the previous version of the specification. If no previous version exists, use the current version UUID.

Property type = UUID
Cardinality = multi

Last Modified Date—The date this object was last modified

Property type = datetime
Cardinality = single

System Id—The identification of the sender/source system that is unique and constant throughout the life of system. DCE assigned string with input from system owner.

Property type = constant unique string
Cardinality = single
Max length = 36 characters

.xml code (example):


```
<cmisra:type xsi:type="cmisTypeDocumentDefinitionType">
    <id>Requirement</id>
    <localName>Requirement</localName>
    <localNamespace>http://dce.nasa.gov/</localNamespace>
    <parentId>cmis:document</parentId>
    <displayName>Requirement Type</displayName>
    <queryName>REQUIREMENT</queryName>
    <description>The DCE Requirement Type</description>
    <baseId>cmis:document</baseId>
    <creatable>true</creatable>
    <fileable>true</fileable>
    <queryable>false</queryable>
    <fulltextIndexed>false</fulltextIndexed>
    <includedInSupertypeQuery>true</includedInSupertypeQuery>
    <controllablePolicy>false</controllablePolicy>
    <controllableACL>false</controllableACL>
    <versionable>false</versionable>
    <contentStreamAllowed>NOT_ALLOWED</contentStreamAllowed>
    <propertyStringDefinition>
        <id>UUID</id>
        <localName>UUID</localName>
        <displayName>UUID</displayName>
        <queryName>UUID</queryName>
        <description>The unique identifier for the object</description>
        <propertyType>string</propertyType>
        <cardinality>single</cardinality>
        <updatability>readwrite</updatability>
        <inherited>false</inherited>
        <required>true</required>
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    </propertyStringDefinition>
    <propertyStringDefinition>
        <id>FromUUID</id>
        <localName>FromUUID</localName>
        <displayName>FromUUID</displayName>
        <queryName>FromUUID</queryName>
        <description>A list of From UUIDs</description>
        <propertyType>string</propertyType>
        <cardinality>multi</cardinality>
        <updatability>readwrite</updatability>
        <inherited>false</inherited>
        <required>false</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
    </propertyStringDefinition>
    <propertyStringDefinition>
        <id>ToUUID</id>
        <localName>ToUUID</localName>
        <displayName>ToUUID</displayName>
        <queryName>ToUUID</queryName>
        <description>A list of To UUIDs</description>
        <propertyType>string</propertyType>
        <cardinality>multi</cardinality>
        <updatability>readwrite</updatability>
```

```
        <inherited>false</inherited>
        <required>false</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
    </propertyStringDefinition>
    <propertyStringDefinition>
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        <displayName>Name</displayName>
        <queryName>Name</queryName>
        <description>The name of the requirement</description>
        <propertyType>string</propertyType>
        <cardinality>single</cardinality>
        <updatability>readwrite</updatability>
        <inherited>false</inherited>
        <required>true</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
    </propertyStringDefinition>
    <propertyStringDefinition>
        <id>Number</id>
        <localName>Number</localName>
        <displayName>Number</displayName>
        <queryName>Number</queryName>
        <description>The number of the requirement</description>
        <propertyType>string</propertyType>
        <cardinality>single</cardinality>
        <updatability>readwrite</updatability>
        <inherited>false</inherited>
        <required>true</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
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    <propertyStringDefinition>
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        <localName>Lifecycle State</localName>
        <displayName>Lifecycle State</displayName>
        <queryName>Lifecycle State</queryName>
        <description>The lifecycle state of the requirement</description>
        <propertyType>string</propertyType>
        <cardinality>single</cardinality>
        <updatability>readwrite</updatability>
        <inherited>false</inherited>
        <required>true</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
        <openChoice>false</openChoice>
        <choice displayName="In-Work">
            <value>In-Work</value>
        </choice>
        <choice displayName="Completed">
            <value>Completed</value>
        </choice>
        <choice displayName="Accepted">
            <value>Accepted</value>
        </choice>
```

```xml
            <choice displayName="Obsolete">
                <value>Obsolete</value>
            </choice>
        </propertyStringDefinition>
        <propertyStringDefinition>
            <id>Requirement</id>
            <localName>Requirement</localName>
            <displayName>Requirement</displayName>
            <queryName>Requirement</queryName>
            <description>The text of the requirement (shall statement)
            </description>
            <propertyType>string</propertyType>
            <cardinality>single</cardinality>
            <updatability>readwrite</updatability>
            <inherited>false</inherited>
            <required>true</required>
            <queryable>false</queryable>
            <orderable>false</orderable>
        </propertyStringDefinition>
        <propertyStringDefinition>
            <id>Rationale</id>
            <localName>Rationale</localName>
            <displayName>Rationale</displayName>
            <queryName>Rationale</queryName>
            <description>The reasoning behind the requirement</description>
            <propertyType>string</propertyType>
            <cardinality>single</cardinality>
            <updatability>readwrite</updatability>
            <inherited>false</inherited>
            <required>false</required>
            <queryable>false</queryable>
            <orderable>false</orderable>
        </propertyStringDefinition>
        <propertyStringDefinition>
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            <localName>Comment</localName>
            <displayName>Comment</displayName>
            <queryName>Comment</queryName>
            <description>A comment about the object</description>
            <propertyType>string</propertyType>
            <cardinality>single</cardinality>
            <updatability>readwrite</updatability>
            <inherited>false</inherited>
            <required>false</required>
            <queryable>false</queryable>
            <orderable>false</orderable>
        </propertyStringDefinition>
        <propertyStringDefinition>
            <id>Category</id>
            <localName>Category</localName>
            <displayName>Category</displayName>
            <queryName>Category</queryName>
            <description>The category of the requirement</description>
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            <cardinality>single</cardinality>
            <updatability>readwrite</updatability>
```

```xml
        <inherited>false</inherited>
        <required>false</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
        <openChoice>false</openChoice>
        <choice displayName="Constraint">
            <value>Constraint</value>
        </choice>
        <choice displayName="Functional">
            <value>Functional</value>
        </choice>
        <choice displayName="Interface">
            <value>Interface</value>
        </choice>
        <choice displayName="Performance">
            <value>Performance</value>
        </choice>
        <choice displayName="Physical">
            <value>Physical</value>
        </choice>
        <choice displayName="Technical Performance Measure">
            <value>Technical Performance Measure</value>
        </choice>
        <choice displayName="Verification">
            <value>Verification </value>
        </choice>
        <choice displayName="Operational">
            <value>Operational</value>
        </choice>
        <choice displayName="Maintenance">
            <value>Maintenance</value>
        </choice>
    </propertyStringDefinition>
    <propertyStringDefinition>
        <id>VerificationMethod</id>
        <localName>VerificationMethod</localName>
        <displayName>Verification Method</displayName>
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        <description>The verification method of the requirement</description>
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        <cardinality>multi</cardinality>
        <updatability>readwrite</updatability>
        <inherited>false</inherited>
        <required>false</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
        <openChoice>false</openChoice>
        <choice displayName="Test">
            <value>Test</value>
        </choice>
        <choice displayName="Demonstration">
            <value>Demonstration</value>
        </choice>
        <choice displayName="Inspection">
            <value>Inspection</value>
        </choice>
```

```
        <choice displayName="Analysis">
            <value>Analysis</value>
        </choice>
    </propertyStringDefinition>
    <propertyStringDefinition>
        <id>PreviousVersionUUID</id>
        <localName>PreviousVersionUUID</localName>
        <displayName>PreviousVersionUUID</displayName>
        <queryName>PreviousVersionUUID</queryName>
        <description>The previous version UUID. If no previous version exists
            then use the current version UUID
        </description>
        <propertyType>string</propertyType>
        <cardinality>single</cardinality>
        <updatability>readwrite</updatability>
        <inherited>false</inherited>
        <required>true</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
    </propertyStringDefinition>
    <propertyDateTimeDefinition>
        <id>LastModificationDate</id>
        <localName>LastModificationDate</localName>
        <localNamespace>LastModificationDate</localNamespace>
        <displayName>Last Modified Date</displayName>
        <queryName>LastModificationDate</queryName>
        <description>The date this object was last modified</description>
        <propertyType>datetime</propertyType>
        <cardinality>single</cardinality>
        <updatability>readwrite</updatability>
        <inherited>false</inherited>
        <required>true</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
    </propertyDateTimeDefinition>
    <propertyStringDefinition>
        <id>SystemId</id>
        <localName>SystemId</localName>
        <displayName>System ID</displayName>
        <queryName>SystemId</queryName>
        <description>The System Identification of the sender</description>
        <propertyType>string</propertyType>
        <cardinality>single</cardinality>
        <updatability>readwrite</updatability>
        <in– format herited>false</inherited>
        <required>true</required>
        <queryable>false</queryable>
        <orderable>false</orderable>
    </propertyStringDefinition>
</cmisra:type>
```


16.4 FORMAT: As specified (RIF/ReqIF™ compatible, preferably in/via the extensible markup language (XML) template provided)

16.5 **MAINTENANCE:** As long as there are requirements—entire life cycle/as changed/modified/updated.

A.13 MASTER RECORDS INDEX (MRI)

DATA REQUIREMENTS DESCRIPTION (DRD)

1. **DPD NO.**: XXX 2. **DPD STATUS**: Draft 3. **DRD NO.**: **STD-MRI**
4. **DATA TYPE: 1** 5. **DATE REVISED:**
6. **PAGE: 1/7**

7. **TITLE:** Master Records Index (MRI)

8. **DESCRIPTION/USE:** Defines the standard of build of the System or End Item, including all associated CIs. The index comprises a key to the approved models, drawings, and associated records and lists all design changes introduced by amendments and modifications. The MRI is used by the Contractor to define the system product as-delivered. The MRI is used by the Government to ensure that the system product meets its build standard and requirements.

9. **OPR:** NASA Configuration Management Office (CMO) or their Representative

10. **DM:** NASA Data Management Office (DMO) or their Representative

11: **DISTRIBUTION:** Per Contracting Officer's letter

12. **INITIAL SUBMISSION:** Submit 90 days post start of build.

13. **SUBMISSION FREQUENCY:** Submit quarterly updates as well as when necessary due to contract changes.

14. **REMARKS:** This DRD is written for use in procurements involving deliveries of digital data sets (involving documents as well as models).

15. **INTERRELATIONSHIPS:**

15.1 The MRI is subordinate to the following data items, where these data items are required under the Contract:
   a. Configuration and Data Management Plan (CDMP);
   b. Systems Engineering Management Plan (SEMP); and
   c. Integrated Support Plan (ISP).

15.2 The MRI inter-relates with the following data items, where these data items are required under the Contract:
   a. Engineering Models/Drawings; and
   b. Master Equipment List (MEL).

16. DATA PREPARATION INFORMATION:

16.1 SCOPE: The data item shall include a traceability matrix that defines how each specific content requirement, as contained in this DRD, is addressed by sections within the data item.

16.2 APPLICABLE ITEMS:
SAE EIA-649, Configuration Management Standard
SAE EIA-649-2, Configuration Management Requirements for NASA Enterprises

16.3 CONTENTS:

16.3.1 As a minimum, the MRI shall consist of the following items and be consistent with SAE EIA-649 and SAE EIA-649-2:

a. Cover Sheet.
b. Index of amendments and modifications.
c. Index of Subsidiary/Subcontractor Master Record Indices.
d. Index of Configuration Items (CIs).
   (1) The Index of CIs shall be developed from data in the Configuration Item List.
   (2) The Index of CIs shall list, in hierarchical form, all the CIs constituting the Mission System.
   (3) The Index of CIs shall be sorted in System and then Subsystem order.
   (4) The Index of CIs shall detail the following information for each CI:
      A. CI Reference Number. This field shall detail the reference number allocated to the CI by the Contractor. This number is to relate the CI to the higher level assembly to which it belongs in a hierarchical manner to system level.
      B. CI Nomenclature. This field shall detail the name allocated to the CI.
      C. CI Type. This field shall detail whether the CI is a Hardware Configuration Item (HWCI) or a Computer Software Configuration Item (CSCI).
      D. HWCI. This field is applicable to CSCIs that reside on HWCIs and shall detail the HWCI in which the CSCI resides.
      E. Subsystem. This field shall detail the CI’s parent Subsystem.
      F. System. This field shall detail the CI’s parent System.
      G. Design Organization. This field shall detail the organization responsible for design of the CI.
      H. Headings. Headings shall be positioned in the Index of CIs to identify where each System and Subsystem begins.
e. Index of Components (IOC)
   (1) The IOC shall detail, in hierarchical form, the physical build structure of the System, going down to and including piece parts.
   (2) The IOC shall be sorted in System, then Subsystem, and then CI order.
   (3) The IOC shall detail the following information for each item in the IOC:
      A. Indenture Level. This field shall document the indenture level of the item; the System is indenture level 1.

B. Part Number. This field shall document the item's Part Number.
C. Variant Number. When more than one variant of an item has been used in the construction of the System, the Part Number of each variant is to be given a variant number (e.g. 1, 2, 3). This field shall default to one (1) when only one variant of an item has been used.
D. Part Number Status. This field shall contain the status of the Part Number (e.g. PROPOSED, CURRENT, OBSOLETE, OR HISTORICAL).
E. Quantity Fitted. This field shall document the quantity of the item fitted to the item's next higher assembly.
F. Drawing Number. This field shall document the Drawing Number of the item.
G. Nomenclature. This field shall document the item's nomenclature.
H. Headings. Headings shall be positioned in the IOC to identify where each System, Subsystem, and CI begins.

f. Indentured Drawing List (IDL)

(1) The IDL shall list, in hierarchical form, all the drawings constituting the System design, including Subcontractor drawings.

(2) The IDL shall detail the following information for each drawing:

A. Indenture Level. This field shall document the indenture level of the drawing.
B. Drawing Number. This field shall document the drawing number.
C. Revision Letter. This field shall document the latest revision letter of the drawing applicable to the System.
D. Drawing Title. This field shall document the title of the drawing.
E. Drawing Type. This field shall document the drawing type to which the drawing belongs, e.g. Detail Assembly Drawing, Specification Control Drawing, Wiring List, etc.
F. Drawing Size. This field shall document the sheet size of the drawing, e.g. A2, A3, etc.
G. Number of Sheets. This field shall document the number of sheets making up the drawing.
H. Revision Date. This field shall document the date of the latest revision.

g. Index of Configuration Documentation (IOCD)

(1) The IOCD shall list the Configuration Documentation describing the functional, allocated, and product baselines for the System (drawings are to be excluded from the IOCD, as they have been listed elsewhere).

(2) The IOCD shall be divided into two (2) sections as follows:

A. Sort Section 1 in System, then Subsystem, then CI order.
B. Sort Section 2 in Document Type and then Document Reference Number order.

(3) The IOCD shall detail the following information for each document:

A. CI Reference Number. This field shall detail the CI Reference Number to which the document is applicable.
B. CI Nomenclature. This field shall detail the CI's nomenclature.

C. Document Reference Number. This field shall detail the document's reference number.
D. Document Revision Number. This field shall detail the revision number/level of the document.
E. Document Type. This field shall detail the type of document to which the document belongs and include the following types of Configuration Documentation, as a minimum, where produced:
   i. System Specifications.
   ii. Development Specifications.
   iii. Product Specifications.
   iv. Interface Control Documents.
   v. Software Requirements Specifications.
   vi. Interface Requirements Specifications.
   vii. Software Product Specifications.
   viii. Software Version Descriptions.
   ix. Software Design Descriptions.
   x. Interface Design Descriptions.
   xi. Database Design Descriptions.
   xii. Materials Specifications.
   xiii. Process Specifications.
F. Revision Date. This field shall document the date of the latest revision.
G. Headings. Headings shall be positioned as follows:
   i. In Section 1 to indicate where each System, Subsystem, and CI begins.
   ii. In Section 2 to indicate where each Document Type begins.

h. <u>Index of Technical Manuals (IOTM)</u>

(1) The IOTM shall list the technical manuals developed under the Contract.
(2) The IOTM shall be divided into two (2) sections:
   A. Sort Section 1 in System, then Subsystem, then CI order.
   B. Sort Section 2 in AAP Number, then Contractor Reference Number order.
(3) The IOTM shall detail the following information for each Technical Manual:
   A. Publication Number or Equivalent. This field shall detail the Publication Number or equivalent allocated to the Technical Manual. Where there is no need to allocate a Publication Number to a Technical Manual, this field is to contain the following entry: NOT REQUIRED.
   B. Contract CAGE Code Number. This field shall detail the authoring Contractor's CAGE Code Number for the Technical Manual.
   C. Title. This field shall detail the title of the Technical Manual.
   D. Related CIs. This field shall detail the Configuration Items to which the Technical Manual is applicable.
   E. Headings. Headings shall be positioned as follows:
      i. In Section 1 to indicate where each System, Subsystem, and CI begins.
      ii. No headings need to be positioned in Section 2.

i. <u>Index of Major (Class I) Engineering Change Proposals (ECPs)</u>
   (1) The Index of Major ECPs shall document all Major ECPs raised against the System and its constituent items during the Contract, including those raised by the Subcontractors.
   (2) The Index of Major ECPs shall detail the following information for each ECP:
      A. ECP Number. This field shall document the unique ECP identification number.
      B. ECP Revision Letter. This field shall document the revision level of the ECP.
      C. ECP Justification Code. This field shall document the ECP Justification Code. (Refer to information defined in MIL-HDBK-61A, Configuration Management Guidance.)
      D. ECP Title. This field shall document the title of the ECP.
      E. Date Raised. This field shall document the date the ECP was raised.
      F. ECP Status. This field shall document the status of the ECP.
      G. Status Change: This field shall document the date the status of the ECP changes.
      H. Configuration Control Board (CCB) Decision. This field shall document the decision made by the CCB.
      I. Decision Date. This field shall document the date of the CCB decision.
      J. Impacted CIs. This field shall document the CIs impacted by the ECP.
      K. Affected Part Numbers. This field shall document the CI Part Number variants impacted by the ECP.
      L. New Part Numbers. This field shall document the new CI Part Number variants introduced as a result of the ECP. Where the new Part Number is simply a re-identification of an existing Part Number, this relationship shall be clearly shown.
      M. Production Effectivity. This field shall document the production effectivity of the ECP.
      N. Retrofit Effectivity. This field shall document the retrofit effectivity of the ECP.

j. <u>Index of Minor (Class II) Engineering Change Proposals (ECPs)</u>
   (1) The Index of Minor ECPs shall document all Minor ECPs raised against the System and its constituent items during the Contract, including those raised by the Subcontractors.
   (2) The Index of Minor ECPs shall detail the following information for each ECP:
      A. ECP Number. This field shall document the unique ECP identification number.
      B. ECP Revision Letter. This field shall document the revision level of the ECP.
      C. ECP Title. This field shall document the title or a brief description of the ECP.
      D. Date Raised. This field shall document the date the ECP was raised.
      E. ECP Status. This field shall document the status of the ECP.
      F. Approval Authority. This field shall document who approved or rejected the

ECP.
G. Decision Date. This field shall document the date the approval authority approved or rejected the ECP.
H. Impacted CI. This field shall document the CI impacted by the ECP.
I. CI Part Numbers. This field shall document the CI Part Number variants impacted by the ECP.
J. Production Effectivity. This field shall document the production effectivity of the ECP.

k. Index of Requests for Variance (RFVs)
(1) The Index of RFVs shall document all RFVs raised against the System and its constituent items during the Contract, including those raised by the Subcontractors.
(2) The Index of RFVs shall be divided into three (3) sections as follows:
A. List RFVs classified as Critical in Section 1.
B. List RFVs classified as Major in Section 2.
C. List RFVs classified as Minor in Section 3.
(3) Each section shall be further subdivided into two (2) subsections as follows:
A. Sort subsection 1 in RFV Reference Number order.
B. Sort subsection 2 in System, then Subsystem, then CI order.
(4) The Index of RFVs shall detail the following information for each RFV:
A. RFV Reference Number. This field shall document the unique RFV identification number.
B. RFV Title/Description. This field shall document the title or provide a brief description of the RFV.
C. RFV Class. This field shall document the class of the RFV, i.e. Critical, Major, or Minor.
D. Date Raised. This field shall document the date the RFV was raised.
E. RFV Status. This field shall document the status of the RFV.
F. Approval Authority. This field shall document who approved or rejected the RFV.
G. Decision Date. This field shall document the date the approval authority approved or rejected the RFV.
H. Impacted CI. This field shall document the CI impacted by the RFV.
I. CI Part Number. This field shall document the CI Part Number variant impacted by the RFV.
J. Affected Part Number. This field shall document the Part Number of the item subject to the RFV.
K. Affected Serial Numbers. This field shall document the Serials Number(s) of the item subject to the RFV.
L. Maintenance-Managed Item (MMI) Part Number. If the affected item is not an MMI and does not build directly to the CI, then this field shall document the Part Number of the higher level MMI.

M. MMI Serial Number(s). This field shall document the Serial Number(s) of the MMI specified at subparagraph L above.
N. Headings. Headings shall be positioned in Subsection 2 to indicate where each System, Subsystem, and CI begins. No headings need to be positioned in Subsection 1.

l. Index of Ancillary Equipment (IAE)

(1) The IAE shall list the support and test equipment (S&TE) and training equipment (hereinafter known as Ancillary Equipment) required to support the maintenance/operation of the System and its constituent items.

(2) The IAE shall be divided into two (2) sections as follows:

A. Sort Section 1 by Ancillary Equipment Type, then by Ancillary Equipment Designation.
B. Sort Section 2 by Supported CI, then Ancillary Equipment Type, then Ancillary Equipment Designation order.

(3) The IAE shall detail the following information for each piece of Ancillary Equipment:

A. Ancillary Equipment Designation. This field shall document the designation of the Ancillary Equipment.
B. Nomenclature. This field shall document the nomenclature of the Ancillary Equipment.
C. Ancillary Equipment Type. This field shall document the support equipment type to which the Ancillary Equipment belongs (e.g. Ground Support Equipment, Automatic Test Equipment, Special Tool Type Tooling, etc.)
D. Supported CI(s). This field shall document the CI(s) supported by the Ancillary Equipment.
E. CI Part Number Variant(s). This field shall document the CI Part Number Variant(s) supported by the Ancillary Equipment.
F. Affected Part Numbers. If the item(s) supported by the Ancillary Equipment is/are below the CI level, then this field shall document the Part Number(s) of the item(s) supported by the Ancillary Equipment.
G. Headings. Headings shall be positioned as follows:
   i. In Section 1 to indicate where each Ancillary Equipment Type begins.
   ii. In Section 2 to indicate where each CI begins.

16.4 **FORMAT**: An MRI template will be made available from the Government, supplier digital formats (e.g. Microsoft® Excel®, comma-separated values [CSV], extensible markup language [XML], etc.) acceptable upon approval by the Government.

16.5 **MAINTENANCE:** Changes shall be incorporated by complete revision/reissue and submitted per item 13, SUBMISSION FREQUENCY, in this DRD.

A.14 CONTRACT LANGUAGE FOR DATA ACQUISITION AND INTEROPERABILITY

A.14.1 Data Acquisition

This section provides guidance for ensuring that NASA provides data acquisition requirements to enable the reference and reuse of data through a program/project's full life cycle.

Data acquisition requirements should be initially presented during Requests for Proposal (RFP)/Request for Quote (RFQ) development to establish integrated data architecture for a program/project's information systems architecture, data architecture, and information systems capability roadmap. The ability to meet data interoperability requirements should be a part of the contract performance metrics on which the Contractor has to report and be evaluated throughout contract execution. This recommended contract language should be applied to the Center's data procurement documents.

The following contract language is categorized based on the type of data interoperability being performed. Also included is contract language pertaining to metadata and data transmittal:

a. Proprietary Formatted Data includes data that is generated on a commercial off-the-shelf (COTS) or custom-built application where the application's data format is proprietary to those systems. The Contractor should provide or deliver the following:

(1) A definition of the application and version that produced the file.
(2) The native proprietary file itself.
(3) A commonly readable representation of the file (Joint Photographic Experts Group [JPEG, JPG], Graphics Interchange Format [GIF], Portable Network Graphics [PNG], or machine-readable Portable Document Format/Archivable [PDF/A]).
(4) The application (source code and executable), with the concurrence of the NASA Contracting Officer's Representative, required to read the native file format for file types where there is no commonly readable representation of the file.
(5) Object Management Group (OMG), 2D/3D formats, videos, neutral and/or 3D PDF files.

b. Structured Digital Data from a Source Repository is digital data extraction from a source data repository provided in a computer-readable format that maintains the referential integrity of the data.

(1) The Contractor shall provide structured, computer-readable data, including all relationships between data, in one of the following formats:

A. Where Extensible Markup Language (XML) is applied, the Contractor should implement an architecture that complies with the applicable NASA IT standards and enable digital data interoperability within NASA domains, World Wide Web Consortium (W3C) XML, W3C Namespaces for XML, and W3C XML Schema.
B. Where XML is applied, the Contractor should respond to NASA's requests for IT data items via W3C XML, W3C XML Namespaces, W3C XML Schema, and OMG XML Metadata Interchange (XMI) for Models.
C. For standard XML digital data descriptions to be usable, all producers and consumers of digital data should reference a common data dictionary as defined by NASA. If a NASA standard is not applicable or available, digital data should reference a common data dictionary as defined by the Contractor that includes the following:

   i. Database output format (e.g. Structured Query Language (SQL) output).
   ii. Structured database output files should include the database type and version (e.g. MySQL2, version 5.5.1).
   iii. The Contractor should provide computer-readable definitions of record structure (schema) for both XML and database output formats.

c. Document-Formatted Data describes documents created in established text-processing applications. Document data should be delivered in a digital form in one of the following formats:

(1) Text-searchable (machine-readable) PDF (rather than scanned PDF).
(2) Microsoft® Word® and Microsoft® Excel® files.
(3) Other commonly readable format (e.g. a text file (.txt), or rich text format (.rtf)) approved by NASA**.**

d. Metadata describes the contents of digital files. Metadata should be defined in a computer-readable data format to support automation and facilitate data interoperability.

(1) Descriptive metadata describes an information resource for identification and retrieval through elements such as title, author, and abstract.
(2) Structural metadata documents relationships within and among objects through elements such as links to other components (e.g. how pages are put together to form chapters).

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[2]MySQL is a relational database management system that runs as a server providing multi-user access to a number of databases.

(1) Administrative metadata helps to manage information resources through elements such as version number, archiving date, and other technical information for purposes of file management, rights management and preservation.

Metadata should be cataloged and published for reuse by all program/project teams to facilitate proper data interoperability.

(1) Acceptable metadata formats include:

A. Comma-Separated Value (CSV) format.
B. XML format.
C. Other fully documented, standards-based format approved by NASA such as embedded PDF/A documents.

(2) Metadata should be delivered with the file to which it is related and reference the filename or other identifying features (e.g. timestamp).
(3) The Contractor should apply ISO 10303-233, Industrial automation systems and integration - Product data representation and exchange - Part 233: Application protocol: Systems engineering, as a foundation for defining common system engineering metadata.
(4) The Contractor should apply ISO 10303-239, Industrial automation systems and integration - Product data representation and exchange - Part 239: Application protocol: Product life cycle support**,** for common systems engineering metadata.
(5) Metadata used during a program/project phase should be defined more than 90 days prior to its first use.

e. Transmittal of data should be via one of the following options; the data transmission method should be defined in each DRD and Statement of Work (SOW)/Performance Work Statement (PWS):

(1) View data in Contractor systems should support viewing data within the Contractor's electronic system in a format readable by a standard NASA workstation or otherwise approved by NASA. This action will be deemed as a delivery of data in place, and such data will be maintained within the Contractor's system.
(2) Direct entry to NASA's system should include direct user entry of data into a NASA-owned system, including fields, values, or other information as required by the NASA system.
(3) Upload to NASA file repository should include uploading files, whether document-formatted data or structured data (e.g. SQL output), and completing any associated data as required by the formats (above) and the file repository,

including Center, program/project, or other specific repository specified in the DRD.

(4) A system-to-system connection should provide an automated capability to pass computer-readable data between a Contractor and NASA system, across Contractor and NASA firewalls, via one of several mechanisms, including, but not limited to:

A. Representational State Transfer (REST) application programming interface (API) for digital data delivery via Internet-based communication (data defined by either a NASA or Contractor standard data exchange format).
B. Simple Object Access Protocol (SOAP) API for digital data delivery via Internet-based communication.
C. Fully documented, standards-based API supported by Contractor tools approved by NASA.

(5) The Contractor should encrypt sensitive information during transmission.

A. The Contractor should utilize the National Institute of Standards and Technology (NIST) 800 Series Publications and FIPS PUB 140-2, Security Requirements for Cryptographic Modules, to meet data encryption requirements.

f. Data Interoperability

This section provides recommended requirement language for guidance in defining data interoperability via industry standards, information systems architecture, and data architecture best practices. A tailored set of the following statements should be included as needed in RFPs and planning documents:

(1) Data is an essential enabler and should be made visible, accessible, and understandable to any potential user as early as possible in the program/project's life cycle to support project and mission objectives as constrained by security and access needs.

(2) Data assets should be made visible by creating and associating metadata ("tagging"), including, but not limited to, discovery metadata, for each asset.

(3) Developed metadata standards should comply with applicable national and international consensus standards for metadata interoperability; all metadata should be retrievable using the NASA Centers' systems with requirements to access the metadata.

(4) Data assets should be accessible by making data available in shared spaces; all data assets should be accessible to all users at the NASA Center except where limited by law, policy, or security classification.

(5) Data that is accessible to all users at the NASA Center should conform to that Center's specified data publication methods that are consistent with the Center's current and planned information systems capabilities.

(6) To enable trust, data assets should have associated information assurance and security metadata and an identified authoritative Contractor and/or Center-level source for the data.

(7) Data interoperability should be enabled through business and mission processes reusing the Center's information system capabilities.

(8) Semantic and structural agreements for data interoperability should be promoted through communities consisting of data users (producers and consumers) and system developers.

(9) Data interoperability concepts and practices should be incorporated into education and awareness training and Center-level processes.

(10) Programs/projects should acquire the minimum essential Contractor-originated data required to meet all program/project life-cycle requirements.

(11) Program/project managers and delegated Technical Authorities should consider data requirements for future procurement needs in a manner that fosters competitive procurement opportunities.

To allow for data interoperability, program/project managers and delegated Technical Authorities should ensure that Contractor data delivered to authoritative sources are acquired through the contract and that DRDs specify data to be delivered in specified digital data formats in lieu of "Contractor format acceptable" or similar language:

(1) Contracts should specify the required delivered data transaction scope, data delivery formats, metadata, naming standards, and data interoperability standards. The definition of data formats and transaction sets should be independent of the method of access or delivery.

(2) Regardless of the format of acquired data, the Contractor should mark any data provided with less than unlimited rights with the appropriate legend as set forth in FAR 52.227-14, Alternates II and III, Rights in Data—General.

(3) Contractors should obtain approval from the NASA Center for all proposed contractual deviations from existing data standards and specifications.

Program/project managers and delegated Technical Authorities should ensure that data is acquired with sufficient access and usage rights to support the full range of program/project needs. This includes, but is not limited to, the following:

(1) The need for data to be used by organizations outside NASA (e.g. support Contractors and companies bidding on new procurements).

(2) In instances when NASA acquires data with less than unlimited rights, the impact to the full program/project is to be assessed.

(3) The Contracting Officer and the cognizant legal office should be consulted to develop a strategy to mitigate any adverse impacts associated with the limited or restricted data rights.

(4) Program/project managers and delegated Technical Authorities should include language in the statement of work to address the marking of data (e.g. "The Contractor should determine the data restriction that applies to each data deliverable and mark or transmit the data restriction in accordance with section X.X of the Data Procurement Document.").

Incrementally define a:

(1) Common vocabulary to support each phase of the program/project life cycle as exit criteria for a program/project life-cycle phase.

(2) Common program/project data dictionary to support each phase of the program/project life cycle. This activity should be performed as program/project phase exit criteria to support the startup of the next phase.

(3) Common namespace standards to support each phase of the program/project life cycle as exit criteria for a program/project life-cycle phase.

If a NASA-/Center-level common vocabulary, common program/project data dictionary, or common namespace standard exists, then the contract should ensure that developed solutions use these common architecture elements.

A.15 RECOMMENDED CONFIGURATION AND DATA MANAGEMENT (CDM) STATEMENT OF WORK SECTIONS FOR CONTRACTS (DRDs to be referenced/added as required)

A.15.1 CDM001

1. CONFIGURATION AND DATA MANAGEMENT

1.1 Configuration and Data Management Planning

1.1.1 The Contractor shall develop, deliver, and update a Configuration and Data Management Plan (CDMP) in accordance with DRD No. STD/CDMP.

1.1.2 The Contractor shall manage and coordinate all Contractor and subcontractor configuration and data management (CDM) activities.

1.1.3 The Contractor shall conduct all CDM activities for the contract in accordance with the approved CDMP.

1.1.4 The Contractor shall ensure that all subcontractors comply with the requirements of the CDMP and are integrated into the Contractor's CDM activities.

1.1.5 The Contractor shall conduct its CDM activities in accordance with GEIA-859, Data Management, SAE EIA-649-2, Configuration Management Requirements for NASA Enterprises, or a NASA [Enter Center]-approved equivalent, as tailored by the approved CDMP.

1.2 Configuration and Data Identification

1.2.1 The Contractor shall identify all recommended CIs that constitute the contractual end item and support system components for NASA's review and approval during the conceptual level.

1.2.2 The Contractor shall uniquely identify all documents that disclose the performance, functional, and physical attributes for each of the approved CIs so that they may be accurately associated with the Configuration Baselines for these systems.

1.2.3 The Contractor shall utilize the Government's Commercial and Government Entity (CAGE) Code and supplied drawing formats and numbers ensuring Government's unlimited data rights.

1.3 Configuration and Data Baselines

1.3.1 The Contractor shall develop and maintain at least each of the following configuration and data baselines for each Mission System and the Support System during the contract:

a. Functional Baseline,

b. Allocated Baseline, and

c. Product Baseline.

1.4 Configuration and Data Control

1.4.1 The Contractor shall manage configuration and data changes and variations, including their:

a. Identification,

b. Process change requests and submit proposed engineering changes for evaluation and disposition by the appropriate Configuration and Data Approval Authority in accordance with DRD No. STD-CR,

c. For configuration changes only, classification as Major Changes or Minor Changes per SAE EIA-649-2,

d. Evaluation and coordination, and

e. Implementation and verification of the changes.

1.4.2 The Contractor shall submit change requests (CRs) supplemented by Engineering Change Proposals (ECPs) in accordance with the approved CDMP to implement changes to Approved Functional, Allocated, and Product Baselines.

1.4.3 All changes to a Functional Baseline shall be classified as a Major Change.

1.4.4 The Contractor shall classify changes to a Product Baseline as either a Major Change or a Minor Change.

1.4.5 The Contractor shall submit all proposed Major Changes to the Product Baseline to the NASA [Enter Center] Configuration Management Organization (CMO) Representative for approval as CRs supplemented by ECPs.

1.4.6 The Contractor shall submit all proposed Minor Changes to the Product Baseline to the NASA [Enter Center] CMO Representative for review.

1.4.7 At the request of the NASA [Enter Center] CMO Representative, the Contractor shall resubmit a proposed Minor Change to the Product Baseline as a proposed Major Change to that Product Baseline in accordance with clause 1.4.5.

1.4.8 The Contractor shall, for any proposed change to a Configuration or Data Baseline, ensure that all Configuration and Data Baselines will be mutually consistent and compatible.

1.5 Configuration Status Accounting

1.5.1 The Contractor shall establish and maintain, in accordance with the approved CDMP, a Configuration Status Accounting (CSA) system that correlates, stores, maintains, and provides readily available views of all configuration information relating to the CIs' components and their respective Configuration Baselines.

1.5.2 The Contractor shall provide all facilities and assistance reasonably required by the NASA [Enter Center] CDM Representative(s) for the NASA [Enter Center(s)] to access the Contractor's CSA system for the duration of the contract.

1.5.3 The Contractor shall deliver reports to the NASA [Enter Center] CDM Representative(s) from the Contractor's CSA system in accordance with DRD No. STD-CSA.

1.6 Configuration and Data Audits

1.6.1 The Contractor shall develop, deliver, and update a Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA) Documentation Plan in accordance with DRD No. STD-AD.

1.6.2 The Contractor shall conduct a Mandated System Review, the FCA, on each delivered CI.

1.6.3 The Contractor's entry criteria, exit criteria, and objectives for FCA shall include those defined in SAE GEIA-HB-649, Configuration Management Standard Implementation Guide, or NASA-provided FCA template (e.g. DRD No. STD-AD).

1.6.4 The Contractor shall conduct a Mandated System Review, the PCA, on each delivered contractual end item and support system components.

1.6.5 The Contractor's entry criteria, exit criteria, and objectives for PCA shall include those defined in SAE GEIA-HB-649 or NASA-provided FCA template.

1.6.6 The Contractor shall invite the NASA [Enter Center] Representative to witness all Materiel System FCAs and PCAs.

1.6.7 Unless otherwise notified in writing by the NASA [Enter Center] CDM Representative(s), the NASA [Enter Center] CDM Representative or appointed representative(s) shall witness configuration and data audits that are conducted for the purposes of acceptance.

1.6.8 Unless the NASA [Enter Center] Representative has notified that it will not witness a configuration and data audit in accordance with clause 1.6.7, the Contractor shall not conduct that configuration and data audit in the absence of NASA [Enter Center] witnesses.

1.6.9 The Contractor shall plan for and support the NASA [Enter Center] CDM Representative(s) performing CDM Process Audits (CDMPA) in accordance with DRD No. STD-CDMPA. The [Enter Center] CDM Representative(s) will audit the Contractor's and its Suppliers' processes to ensure that each organization is compliant with the CDM requirements of the contract and that the configuration baselines are correctly defined, controlled, accounted for, and verified, and any required corrective actions resulting from CDMPAs are implemented.

1.7 Interface Control

Note to Offeror: NASA [Enter Center] expects to manage the system interface design process through the Interface Control Working Group (ICWG) forum or prior agreed-to process. Whenever possible, the Contractor is encouraged to liaise directly with third party Contractors and use the ICWG forum for final agreement or dispute resolution.

1.7.1 The Contractor shall conduct NASA [Enter Center]-sponsored Interface Control Working Groups (ICWGs) to establish and refine the Materiel System external interfaces and the platform integration and installation design.

1.7.2 The Contractor shall provide sufficient design information to the ICWG, including provision to third parties, to enable the interface details to be established.

1.7.3 The Contractor shall organize and conduct the ICWGs as extraordinary-/additional meetings in accordance with associated clauses for:

a. Each external interface identified.

b. Any other external interfaces identified during system design.

1.7.4 Membership of ICWGs shall include the NASA [Enter Center] CMO, the Contractor, and the relevant interface [Enter Interface Name, e.g. Electrical Ground Support System] Program Office.

1.7.5 The Contractor shall develop, deliver, and update a design document in accordance with DRD No. STD-MBx, detailing the interface design for each of the relevant external interfaces.

1.7.6 The Contractor shall submit the relevant draft design document detailing the interface design to the NASA [Enter Center] Representative prior to the ICWG.

1.7.7 Unless otherwise agreed by the NASA [Enter Center] Representative, the Contractor shall obtain endorsement of the relevant design document detailing the interface design from each ICWG prior to Critical Design Reviews.

1.7.8 ICWGs shall be held at venues to be determined by the NASA [Enter Center] CMO.

Note to Tenderers: It is the NASA [Enter Center] CMO's intention that ICWGs be held at [Enter Center].

1.7.9 The expected level of effort required by the Contractor is:

a. Attendance at approximately 12 ICWG meetings annually;

b. For each ICWG meeting, no more than five representatives of the Contractor will be required to attend; and

c. The maximum duration of each ICWG is expected to be no more than two days with one-day duration typical.

1.7.10 The Contractor acknowledges that no statements, representations, or undertaking by the ICWGs or any failings of the ICWGs to meet the requirements detailed above shall affect or undermine the Contractor's requirement to fulfil the Contract.

1.7.11 The parties agree to bear their own costs arising out of any level of effort in excess of the expected ICWG level of effort.

1.8 General

1.8.1 Contractor shall maintain engineering, manufacturing, and quality controls such that all items scheduled for delivery under this contract conform to the CDM requirements set forth below in this Clause. These requirements apply without limitation to each and every end item Contractor delivery to Government under this contract regardless of whether or not such item is a commercial off-the-shelf (COTS) item, catalog item, build-to-print item, Contractor-designed item, Government-designed item, or any combination thereof, etc. As a result thereof, Contractor is responsible for and these requirements apply without limitation to any and all items, parts, assemblies, COTS items, catalog items, or any combination thereof, etc., that Contractor may include in the end item it delivers to Government under this contract.

1.8.2 Contractor shall, at any time after contract award, secure the written consent of Government prior to making any Major*[3] change to the item, if one or more of the following is affected:

a. The function, installation, item's interfaces, or the physical or operational interchangeability of the item, reparable parts, and/or the spares support.

[3] Refer to SAE EIA-649-2, section 3.3.3, Major and Minor Changes

b. Current applicable installation, operation, or other procedures with respect to the use thereof.

c. Certification(s) (e.g. Technical Standard Orders, Certificates of Conformance, Certificates of Compliance, etc.).

d. The specified requirements of performance, weight, safety, reliability, service life, and maintainability.

e. Delivered items (rework, replacement, or maintenance).

f. Qualification status (e.g. item does not meet original qualification requirements; or Contractor makes a change because of component obsolescence, productivity improvement, etc., that requires re-qualification).

1.8.3 Contractor shall give written notice to Government using DRD No. STD-CR or Government-approved Contractor's change form, describing any proposed change as described in paragraph (1.8.2 above) in sufficient detail (including technical, cost, risk, and schedule impact analysis) to enable an understanding by Government of the total impact of the change. Supplemental documentation (exhibits, sketches, drawings, draft retrofit information, etc.) shall be included.

1.8.4 Government will, within 30 days after the receipt of such change request/proposal, advise Contractor of its consent to, its rejection of, or the status of the change under consideration. In no event shall Contractor proceed to incorporate such change into the items ordered by this contract prior to receipt of written consent from the Government.

1.8.5 A new Contractor part number identification shall be assigned to all items to be delivered to the Government when an approved Major change affects interchangeability.

1.8.6 Contractor shall have the right to make **[4] Minor changes under this contract, without obligation to make such changes in any delivered items, without an increase in price, and without prior approval, if the change does not affect any of the factors outlined in A.15.1, section 1.8.2. These changes shall require Government's concurrence in classification.

1.8.7 Contractor shall make revisions to and furnish all data (MBx models, drawings, catalogs, technical manuals, etc.) submitted under this contract that are affected by any change.

1.8.8 Minor changes requiring concurrence in classification shall be submitted immediately to Government's Authorized Procurement Representative using DRD No. STD-CR or Government-approved Contractor's change form and revised data. These changes may be released at the same time for incorporation by Contractor at Contractor's facility. However, no changes shall be incorporated in the item within 30 days prior to the shipment to Government.

[4] Refer to SAE EIA-649-2, section 3.3.3, Major and Minor Changes

Note: All changes incorporated in the item prior to Government's concurrence are done so at Contractor's risk (see 1.8.9).

1.8.9 After concurrence in the classification review of Contractor's revised data, Government reserves the right to reclassify the change and return to Contractor for processing in accordance with A.15.1, sections 1.8.2 through 1.8.5. Contractor shall be notified within 30 days after receipt if Government rejects the change classification. **No response denotes Government's concurrence.**

1.8.10 [Enter Center/Program Form Number], Contractor Request for Information/Clarification, is incorporated herein by reference. This form, or Government-approved Contractor equivalent, shall be used by Contractors to submit inquiries and/or request clarification.

A.15.2 CDM002

CONFIGURATION AND DATA MANAGEMENT – COMPONENTS

These provisions shall apply to all qualified or qualifiable components ordered under this contract for delivery to Government or to Government's customers:

a. Contractor shall maintain configuration and data control of the design and manufacture of the components ordered hereunder, including, but not limited to, formal initial identification of the configuration of the components and controlled internal approval and accountability of changes to drawings, procedures, and other control documents.

b. Contractor shall give written notice to Government describing any proposed change to a component, including the effect of such proposed change, proposed by Contractor to be implemented subsequent to the establishment of the baseline component configuration. Changes include those affecting form, fit, or function of the component; changes to Contractor's drawings, procedures, and other control documents; changes involving a substitution of material; and changes in Government-approved manufacturing processes. Any such proposed change shall be submitted to Government's Authorized Procurement Representative for processing and review by Government.

c. A Contractor Certificate of Conformance shall be included with each shipment.

d. Contractor shall insert the substance of this clause in each lower-tier subcontract for functional components/parts.

e. Noncompliance with the change notification requirement of this clause may result in subsequent rejection of delivered items.

f. Contractor shall be responsible for all reasonable costs incurred by Government or Government's customers as a result of Contractor's failure to comply with the provisions of this clause.

g. Nothing contained in this clause shall excuse Contractor from performing in strict compliance with the terms, conditions, delivery schedule, specifications, or any other provision of this contract.

h. In the event of conflict between this clause and any other provision of this contract, the conflict shall be resolved by Government's Authorized Procurement Representative.

Reference Only

The following DRDs are cited in the above clauses and thereby form part of these contractual requirements:

a. STD-CDMP
b. STD-CR
c. STD-CSA
d. STD-AD
e. STD-CDMPA

APPENDIX B

DATA ACQUISITION CONTRACT LANGUAGE

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1. Objective

The National Aeronautics and Space Administration (NASA) Office of the Chief Information Officer (OCIO), led by the Technology and Innovation (T&I) Division, proposes data requirements language for contracts intended to enable effective interaction and utilization of contractor-generated data and information. Introduction of such requirements language ensures that data acquisitions are appropriately included into NASA contracts, guaranteeing the government does not lose data, information, or knowledge that has been produced during the contract and, ultimately, lowering cost and effort for both parties. T&I proposes new contracts that treat data as a valuable asset and structure data-related deliverables in formats that can be shared, regardless of whether a determination has been made as to whether the data should be made available to the public.

NASA should acquire the minimum, essential contractor-originated data required to meet all program life-cycle requirements. Every attempt should be made to integrate all functional specialties, e.g., safety, reliability, quality, logistics, test and verification, etc., to minimize data acquisition redundancies and inconsistencies. This integrated effort must include sub-projects within the various programs. The requirement to deliver and manage data in a digital environment influences the manner in which data delivery requirements are levied on existing and future contracts. Ongoing contracts should consider contract modifications to require the delivery and management of contractually delivered data in a digital environment on contracts.

The purpose of this Appendix is to provide specific data requirements language to supplement the existing FAR and NASA FAR Supplement (NFS) clauses. This document provides guidance, templates and specific language to enable data integrity, and control and access during and after the contract is awarded.

2. Background

Historically, NASA procurements have overall included very little, if any, data language in contracts to provide the Government readily available access to information produced during contract periods or when transferred after expiration of the period of performance (PoP). The one exception is large programs, and even they have incurred large and often unexpected costs when transferring data to the Government at contract end. This has forced NASA organizations to negotiate with contractors on access during the contract period and the transfer of data at contract end. This has resulted in higher overall costs because the Government essentially does not benefit in tradition procurement terms by allowing the competition of bidders against each other. When contractors turn over data at contract end, they often levy large data conversion costs along with the transfer overheads making the cost of the process higher than expected. Often, contractors will classify data as primarily proprietary or intellectual property during the contract, making any negotiations tougher due to the difficulty of defining who really owns the data. This puts the Government at a disadvantage when trying to negotiate after the contract has been signed.

In an effort to compile the appropriate contract language to ensure data are protected throughout the contract and transferred as required at contract end, the team met with both contractor and civil servant subject matter experts (SMEs) from many previous and existing NASA Programs and institutional and engineering/science organizations. The team summarized lessons learned and documented significant risks and appropriate mitigations with the end goal of developing draft language for consideration and use in future contracts. The draft language will have the appropriate reviews with Legal, Procurement, and appropriate SMEs.

In this effort, the team reviewed and referred to a considerable amount of previously developed white papers and documentation. The team also researched NASA wide for other material and found a significant amount of information concerning data and information available from the NASA Earth Science program. In addition, the NASA Earth Science program developed a Data and Information Policy accessible at http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/, which provided the team valuable information and associated contract language. The team reviewed and utilized language from the Earth Science program, which promotes the full and open sharing of all data with the research and applications communities, private industry, academia, and the general public. The greater the availability of the data[5], the more quickly and effectively the user communities can utilize the information to address basic Earth science questions and provide the basis for developing innovative practical applications to benefit the general public.

3. Lessons Learned

Given the advances in technology over recent decades, it becomes necessary to investigate new, more efficient approaches and business practices to achieve reasonable governmental access to data while simultaneously minimizing cost impacts associated with such requests.

Numerous lessoned learned were identified while looking into the Space Shuttle Program (SSP), International Space Station (ISS), Launch Services Program (LSP), and various other contracts associated with Commercial Crew, Constellation, Orion, and others. The primary lesson learned was if one simply omits data requirements in a contract, access to the data during the contract and at contract end would then become only attainable at additional cost. Inclusion of tailored, template contract language can aide in this regard and ensure critical data access and integrity for the lifespan of the particular record.

[5] For purposes of this document, the term data will be used to cover data, information, and knowledge stored in an information system.

The SSP had numerous issues associated with data over the 30-year program. Data media varied from paper, to microfiche, to digital, making delivery, translation, and/or reuse a significant cost and effort. Additionally, the SSP did not have the data stewardship to ensure that downstream records management could be effectively and efficiently implemented. Security classifications for much of the documentation were not considered at the beginning for items such as export control—sensitive but unclassified (SBU), International Traffic in Arms Regulations (ITAR), etc. As such, huge amounts of backlogged data could not be dispositioned.

The SSP design data and drawings were not contractual deliverables and, in most instances, were further complicated by multiple designs for various systems being developed across the program. This resulted in reference material not being available to multiple Centers across the program.

For the SSP, the resulting theme is the program neither defined nor added contract language to obtain data at the end of the contract, resulting in millions of dollars spent researching and obtaining data.

The ISS program continues to maintain multiple data systems for parts accounting, disposition, management, etc., because not one of their current systems can provide all functionality required; and the form of data does not lend itself to a single management system.

Both the SSP and ISS programs were stuck with huge balloon payments to purchase proprietary code that was required to run and maintain software systems formerly contractor owned and run. Without this code, the data would be unusable or require expensive conversion.

The ISS Payload Processing Contractor was asked at the end-of-contract to turn over SSP work procedures at contract closeout. These work procedures were developed during the contract and were to be turned over to the incoming contractor; however, the contractor deemed many of the subject procedures to contain “trade secrets,” making them proprietary. As such, many of the procedures developed during the life of the Payload Processing Contracts were never obtained and/or turned over. Again, the foresight to identify data required at end-of-contract was never considered at the beginning of the contract, or the contract specified the “best available data” that, while seeming the most economic path, turned out proprietary.

The trend of moving from cost plus contracts to performance-based contracts, in many cases, encouraged contractors to develop and use their own data systems while NASA counterparts became further disengaged in day-to-day activities. This continuing trend to convert more contracts to fixed price can further acerbate the issue of obtaining data as well as the possibility of more intellectual property being owned by the contractor.

The LSP, with the contract strategy of fixed price contracts to further reduce contract cost, has chosen to accept “existing contractor data” to the maximum extent possible. This strategy, although seeming the most cost effective, may become costly in the event the Government has a need to obtain the data at contract end or any time during the contract if specific contract language does not address this data at the inception of the contract.

The Commercial Crew Program (Commercial Crew Development) is proceeding with very little data deliverables resulting in only the interfaces or interface control documents (ICDs) available and only available for describing identified interfaces such as known touch points and enabling determination of safety assurance.

A recent OCIO contract has contract language stating "all Contractor-developed applications shall be owned by NASA and fully transferable, including source code and documentation, to a new vendor at the conclusion of contract."

In summary, data standards vary across NASA programs from no standards to various attempts to establish a standard. Most program managers in the past have had the perception that data will cost a lot of money resulting in data not addressed in most contracts, or data deliverables were removed during one of the many cost-cutting exercises. The most efficient and least expensive method of obtaining data is to include achievable requirements in the RFP or front end of the contract. Any end-of-contract changes will cost significantly more to obtain data.

4. Needs Assessment

The purpose of the needs assessment was to determine the high-level requirements associated with data acquisitions and whether the existing problems associated with data acquisitions are Agency wide or program specific. The needs assessment report is used to develop the future contract language and to enhance its effectiveness. The needs assessment was performed through surveys and focus group discussions. The key findings follow.

4.1 Digital Data Standardization

Digital data standardization, regardless of the file or data format used, is needed for all data deliverables. As such, future procurement solicitations are to address and place emphasis on, but not limit to, the following categories and include as deliverables along with addressing "how to" accomplish them within the SOW and other sections of the RFP:

a. Ensure consistency of data and data use across systems.
b. Ensure minimal redundant data collection and entry.
c. Ensure maximum utilization of relevant technology.
d. Ensure audit trail accessibility.
e. Ensure rapid retrieval of audit trail information for change processing.
f. Ensure effective analysis of metrics.
g. Ensure improved data acquisition time lines.
h. Ensure improved data review and integration.

Digital data standardization is considered and required when the following program requirements exist:

a. The potential for reuse of data in compliance with Office of the Federal Chief Information Officer's Memorandum for the Heads of Executive Departments and Agencies M-13-13, Open Data Policy, in accordance with internal data clearance processes for release to public.
b. A need exists for interoperability of standardized data among Centers, academia, industry, platforms, and contractors/programs.
c. The need to provide relationships between data for performing program management, systems engineering, and operational functions.
d. Contract closeout.

4.2 Data Definition and Interoperability Requirements

NASA must provide data definition and interoperability requirements written into program contracts to leverage a data-centric approach for digital asset data management. The requirements should be defined by NASA policies that generate content for inclusion in NASA Request for Quotes (RFQs), Request for Information (RFI), and Request for Proposals (RFPs) templates and preparation handbooks.

4.3 Data Acquisition

NASA must provide data acquisition requirements to enable the reference and reuse of data through a Program's full life cycle. These data acquisition requirements should be present during RFP/RFQ development to establish integrated data architecture for a Program's information systems architecture (ISA), data architecture (DA), and Information Systems (IS) capability roadmap. The ability to meet data exchange requirements should be a part of the contract performance metrics that the contractor must report on and be evaluated on throughout contract execution.

4.4 Data Rights

NASA must ensure access to technical data (recorded information used to define a design and to produce, support, maintain, or operate a system). This is critical to life-cycle sustainment of a system. Critical decisions made early in the acquisition process address data needs over the entire life cycle of the system.

It is critical for the contractor to assess long-term data rights requirements and corresponding acquisition strategies prior to initiating a response for proposal to acquire systems, subsystems, or end items to ensure they provide for rights, access, or delivery of technical data that the

Government requires for systems' total life-cycle sustainment. Furthermore, the delivery of technical data and associated rights at reviews and documentation of the strategy in the Information Support Plan and associated data planning documents should also be addressed.

NASA must ensure science data is retrieved and accessible for open sharing. Science data products include data sets generated by the project that include the science data itself, associated ancillary data, and aircraft navigation data. The contractor must summarize all science data products to be generated and documentation for correct and independent use of the data. The expected range of use to be supported by this documentation should be indicated. Some types of data sets that should be considered for inclusion are:

- Metadata,
- Low-level processed data,
- High-level processed data,
- Scientific results,
- Science algorithm source code,
- Algorithm theoretical basic documents (ATBDs),
- Data quality documentation.

4.5 Request for Proposal (RFP) Language

There are several areas of the RFP that need language to ensure program data acquisition downstream. In addition, creating a template that includes both prescriptive language and guidance for organizations to describe their data and how they want to access it, allows the organization to customize their instructions to the potential Offerors. Specific sections of the RFP include:

a. SOW – This is where the functional and technical requirements reside within the contract package, typically within Section C of the government request package. The requirements will include the types of data the government identifies for use throughout the life of the contract, how they want to access data, and the process of transferring the data at contract end. The Offeror provides this information in their proposal; however, the information may not be explicit in the contract, but rather is contained within the DRD (Data Requirements Description).

b. DRD – In this case the DRD is a template that requests details for the information that was requested in the SOW. It must be submitted with their proposal. The Offeror should provide the same approach to handling Data as they submitted in their proposal. This remains in the contract within the DRD. Contracting Officers, not always but often, will go to the SOW as the rules of the contract, often at the expense of the DRD. They expect to see the rules in the SOW. For this reason, it needs to be in both places.

c. Cost Volume – The cost of maintaining data in a centralized place, making it accessible to the government, and then transferring the information at contract end has a price tag that is always more than expected. To get the best price, the cost must be set at contract start. To achieve this, the Offerors must submit their cost to the cost volume as a separate line item. This sets the cost at contract start because the cost volume is in the contract. This will be critical for fixed-price contracts.

4.6 Procurement Information Circular (PIC)

To have the data requirement pushed to all NASA procurements that have data requirements (e.g. not hardware or software purchases), a PIC needs to be put in place so all the Contracting Officers understand the data language requirement. The PIC directs them to include it (if it requires data) into each Procurement. They will provide the requirement to the board chairs. The Contracting Officer will not be responsible for understanding the requirements or implementing them. That will be the responsibility of the chair/board member assigned to the action. A document with guidelines and the prescriptive language of how and when to use the data language will accompany the PIC.

4.7 Training

Each Center needs to appoint a point of contact from their Chief Information Officer's (CIO's) office that can work with the boards to guide them through the process. Each POC needs training on the process before working with the boards.

4.8 Proprietary Data and Intellectual Data Rights

NASA recognizes the right of suppliers to create and maintain a competitive advantage. However, NASA seeks access to or acquisition of relevant data for efficiency and safety reasons. Proprietary data and intellectual data rights must be addressed to the extent the contractor cannot label data as proprietary to avoid data sharing. NASA seeks to explore ways to access the necessary data while still respecting the interests of the suppliers. This language is legal in nature and therefore needs to be provided by Legal and Procurement.

5. Contract Language[6]

NASA shall ensure that contractor data delivered to a single authoritative source is acquired through contract, and that Data Requirements Descriptions (DRDs) specify data to be delivered in specified electronic data formats, in lieu of "contractor format acceptable" or similar language. Contracts shall specify the required delivered data transaction scope, data delivery formats, metadata, naming standards, and data exchange standards. The definition of data formats and transaction sets shall be independent of the method of access or delivery. Regardless of the format of acquired data, the contractor shall mark data provided with less than unlimited rights with the appropriate legend as set forth in FAR 52.227-14, Alternates II and III.

See the following sections for specific language for all contracts.

5.1 Model-Based Enterprise (MBE) Plan

The Contractor shall provide an MBE Plan to be approved by the Government for all contracts requiring data[7] deliverables. The MBE Plan will be used to document the data management infrastructure that will be put in place throughout the contract and provide periodic reporting of the data produced by the contract. Refer to Appendix J.

5.2 Data Rights[8]

NASA shall obtain and maintain appropriate data rights for all data produced by the Contractor to be provided to NASA during and at Contract end. NASA shall address intellectual property rights on an individual basis in conjunction with Procurement and Legal Offices.

Contract language should include following:

"The [Agency] owns the rights to all data and records produced as part of this contract. All deliverables under the contract are the property of the U.S. Government for which [Agency] shall have unlimited rights to use, dispose of, or disclose such data contained therein as it determines to be in the public interest. Any Contractor rights in the data or deliverables must be identified as required by 48 CFR § 52.227-11, Patent Rights-Ownership by the Contractor; 48 CFR § 52-227-12, Reserved; 48 CFR § 52-227-13, Patent Rights-Ownership by the Government; 48 CFR § 52.227-14, Alternates II and III, Rights in Data—General; 48 CFR § 52-227-15, Representation

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[6] *This section contains each of the categories and requirements associated with Data Management in contracts. The intent is to choose each category and specific requirement(s) that applies to the contract's use of data. Contracts that have science or engineering as a core competency tend to use the data differently and have different requirements that need to be reflected in the SOW. The individual requirements found in these sections should be viewed as options to be selected as they apply to the contract and use them as appropriate to develop your SOW.*

[7] The term "data" will be used throughout this section to cover the terms data, information, and knowledge.

[8] Issuer's legal organization should be part of standard review process, including all specific binding language.

of Limited Rights Data and Restricted Computer Software; 48 CFR § 52.227-16, Additional Data Requirements; 48 CFR § 52-227-17, Rights in Data-Special Works; 48 CFR § 52-227-18, Rights in Data-Existing Works; 48 CFR § 52-227-19, Commercial Computer Software License; and 48 CFR § 52.227-20, Rights in Data-SBIR Program."

Flow down of requirements to subcontractors:

1. "The Contractor shall incorporate the substance of this clause, its terms and requirements including this paragraph, in all subcontracts under this [contract vehicle], and require written subcontractor acknowledgment of same.
2. Violation by a subcontractor of any provision set forth in this clause will be attributed to the Contractor."

Regarding Federal Acquisition Regulations (FARs):

Government personnel preparing agreements (e.g. RFIs, SOWs, PWS, etc.) need to understand the distinction between:

1. FAR parts and subparts that are guidance and direction to the Government and FAR Clauses, and
2. FAR Parts and Subparts incorporated by Reference, that are Contractually binding upon the Contractor and the Government.

Regarding the term "Data Rights," which is often used to refer to the Government's licensing rights in two major categories of valuable intellectual property:

1. Technical Data (TD) includes any recorded information of a scientific or technical nature (e.g. product design or maintenance data, and computer software documentation (CSD)).
2. Computer software (CS) includes executable code, source code, code listings, design details, processes, flow charts, and related material.

An Intellectual Property Strategy needs to be developed early to help program/project management to ensure that all TD, CS, and associated license rights required for procurement and sustainment of a system are available throughout the system's life cycle.

1. Sustainment activities include re-bid/procurement, maintenance, repair, modifications or interfacing/interoperability activities, and upgrades or technology insertion.
2. A priced option may be used to address uncertainty regarding data deliverables or data rights that may be needed in the future but that are not ordered up front.
3. The deferred delivery clause (DFARS 252.227-7026, Deferred Delivery of Technical Data or Computer Software) and necessary CDRLs are used to delay delivery, when the specific data requirements are known, until the Government determines when the data deliverables should be provided.

4. The deferred ordering clause (DFARS 252.227-7027, Deferred Ordering of Technical Data or Computer Software) is used to delay the ordering of data generated in the performance of a contract until the Government determines what and when additional data is needed.
5. The Data Accession List (DAL) is a useful tool to facilitate deferred ordering.

Data deliverables and data rights issues may be identified and resolved by:

1. Requiring Offerors to assert all restrictions on deliverable TD and CS–both commercial and noncommercial–up front, in their proposals,
2. Evaluating the data deliverables and data rights being offered, and
3. Negotiating for mutually agreeable special license rights where standard license categories do not meet both parties' needs.

The Government's license rights to a contractor's TD and CS generally depend upon the extent to which the Government funded the development of the technology, whether the technology is commercial or noncommercial, and any negotiations for mutually agreeable "special" license agreements. Some types of data qualify for Unlimited Rights regardless of development funding source such as "form, fit, and function (FFF) data" and data necessary for operation, maintenance, installation, and training (OMIT) purposes (excluding detailed manufacturing and process data).

The FAR clauses do not by default require delivery of TD or CS–the Government must include specific delivery requirements in each contract (refer to Table 3, Specific Contract Delivery Requirements). Mere access may not protect the Government's interests. Consider a priced option when needs for data delivery or data rights are uncertain.

Table 3—Specific Contract Delivery Requirements

Rights Category	Applies to These Types of TD or CS	Rights Criteria	Permitted Uses Within the Government	Permitted Uses by Third Parties Outside the Government[1]
Unlimited Rights (UR)	Noncommercial TD and CS	Developed exclusively at Government expense, and certain types of data (e.g., FFF, OMIT, CSD)	All uses; no restrictions	
Government Purpose Rights (GPR)	Noncommercial TD and CS	Developed with mixed funding	All uses; no restrictions	For "Government Purposes" only; no commercial use[1]
Limited Rights (LR)	Noncommercial TD only	Developed exclusively at private expense	Unlimited; except may not be used for manufacture	Emergency repair or overhaul[1,2]
Restricted Rights (RR)	Noncommercial CS only	Developed exclusively at private expense	Only one computer at a time; minimum backup copies; modification[3]	Emergency repair/ overhaul; certain service/maintenance contracts[1,2]

Specifically Negotiated License Rights	Any/all TD and CS – including commercial TD and CS	Mutual agreement of the parties; use whenever the standard categories do not meet both parties' needs	As negotiated by the parties; however, must not be less than LR in noncommercial TD and must not be less that RR in noncommercial CS (consult with legal counsel as other limits apply)
SBIR Data Rights	Noncommercial TD and CS	All TD or CS generated under an SBIR contract	The equivalent of Unlimited Rights (UR) in OMIT and FFF data; the equivalent of Limited Rights (LR) in all other delivered TD; the equivalent of Restricted Rights (RR) in CS
Commercial TD License Rights	Commercial TD only	TD related to commercial items (developed exclusively at private expense)[4]	The equivalent of Unlimited Rights (UR) in OMIT and FFF data; the equivalent of Limited Rights (LR) in all other delivered TD
Commercial CS Licenses	Commercial CS only	Any commercial CS or CS documentation	As specified in the commercial license customarily offered to the public[5]

[1] All third party use under Government's license is subject to Government authorization. For rights categories other than UR, releases or disclosures to third parties must be accompanied by either the Non-Disclosure Agreement (NDA) from 48 CFR § 227.7103-7, Use and Non-disclosure Agreement, or must occur under a contract containing 48 CFR § 252.227-7025, Limitations on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends. A notice requirement also applies to releases of LR data and RR software.
[2] In addition to footnote 1, NDA and notice requirements, all authorized Covered Government Support Contractors with access to LR data or RR software must sign an NDA directly with the owner of the data/software, if required by the owner.
[3] See 48 CFR § 252.227-7014(a), Rights in Noncommercial Computer Software and Noncommercial Computer Software Documentation, for more information.
[4] Commercial items are presumed to have been developed exclusively at private expense, except in the case of major systems [see 48 CFR § 227.7103-13(c)(2), Government Right to Review, Verify, Challenge, and Validate Asserted Restrictions, and 48 CFR § 252.227-7037(b), Validation of Restrictive Markings on Technical Data]. However, when the Government has paid for any portion of development, then the noncommercial TD clause (48 CFR § 252.227-7013, Rights in technical data - Noncommercial items) is used for TD pertaining to those portions, and the commercial TD clause 48 CFR § 252.227-7015, Technical data - Commercial items, is used for TD relating to the portions developed exclusively at private expense [48 CFR § 227.7103-6(a), Contract Clauses].
[5] Such licenses must be consistent with Federal procurement law and satisfy user needs.

5.3 Data Protection and Access

The contractor shall provide secure storage and protection of the data, information, and knowledge that have been developed by the contract, including historical data. All data will be backed up every 30 days at a minimum.

The contractor shall provide access of the data, information, and knowledge that have been developed by the contract, including historical data, to the Government throughout the life of the contract and at the termination of the contract. [State the requirement]. The contractor shall ensure that information is collected in a way that supports downstream processing, and that systems are built to support interoperability and information accessibility, including regular access or exporting of the data as a standard requirement of such systems.

The contractor shall provide public access to the data [State the requirement] as approved by the Government. The contractor will use the approved internal clearance processes established by the agency OCIO in compliance with the Open Data Policy-Managing Information as an Asset (M-13-13).

The contractor shall provide the capability to support [State the number or classification] users. The access includes [define access, usage, and storage capacity]

Any contractor-developed applications, funded by the contractor, shall be owned by NASA and fully transferable, including source code and documentation, to a new vendor at the end of this contract as deemed necessary by the Government.

The contractor and Government will meet [State the number] days prior to the end of the contract to determine the schedule for transferring the data, information, and knowledge to the Government. At the end of the contract, all data, information, and knowledge shall be transferred to the Government.

The contractor shall protect all data produced by the contract in accordance with the IT security policies and procedures in NASA Policy Directive (NPD) 2810.1, NASA Information Security Policy.

5.4 Data Requirements

5.4.1 Proprietary Formatted Data

The following applies to data that is generated on a COTS or a custom-built application where the application's data format is proprietary to those systems:

The Contractor shall provide a definition of the application and version that produced the file.

The Contractor shall provide the native proprietary file itself.

The Contractor shall provide a commonly readable representation of the file approved by the Government [Agency] (e.g. JPG, GIF, PNG, or PDF/A).

For file types where there is no commonly readable representation of the file, and with the concurrence of the NASA Contracting Officer's Representative, the Contractor shall deliver the application (source code and executable) required to read the native file format.

5.4.2 Structured Digital Data from a Source Repository

The following applies to digital data extraction from a source data repository provided in a computer-readable format that maintains the referential integrity of the data:

The Contractor shall provide structured, computer-readable data, including all relationships between data, as follows:

The Contractor shall implement an architecture that complies with the applicable NASA IT Standards and enables digital data sharing within NASA Agency domains, [State the specific standard]. Examples include: W3C XML, W3C Namespaces for XML, and W3C XML Schema for XML data.

The Contractor shall respond to Government requests for IT data items via [State Specific Formats]. Examples include: W3C XML, W3C XML Namespaces, W3C XML Schema, and OMG XMI for Models for XML data.

The Contractor shall ensure digital data descriptions are usable, and all producers and consumers of digital data shall reference a common data dictionary as defined by NASA for standard XML [or state other] data. If a NASA standard is not applicable or available, digital data should reference a common data dictionary as defined by the Contractor.

The Contractor shall ensure a database output format is provided (e.g. SQL output).

The Contractor shall ensure structured database output files include the database type and version (e.g. MySQL, version 5.5.1).

The Contractor shall provide computer-readable definitions of record structure (schema) for both XML and database output formats.

5.4.3 Document Formatted Data[9]

The following applies to documents created in text processing applications:

The Contractor shall ensure data delivered in digital form is provided in text-searchable PDF/A (rather than scanned or raster PDF), or Microsoft® Word® and Microsoft® Excel® files [State any other formats].

The Contractor shall obtain NASA approval prior to digital data delivery of an item not meeting standard formats listed above (e.g. .txt, .rtf).

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[9] It is critical to appropriately include examples of formats typical to the business area.

5.5 Metadata

Metadata shall be defined in a machine-readable data format to support automation and to facilitate data exchange. Metadata should be cataloged and published for reuse by all program teams to facilitate proper data exchange.

The Contractor shall ensure metadata is based on latest NASA-approved industry standard such as, but not limited to, Comma Separated Value (CSV) or Extensible Markup Language (XML) format and consistent with requirements defined in the Structured Digital Data section.

The Contractor shall obtain NASA approval for fully documented, standards-based formats not listed above (e.g. embedded PDF documents).

The Contractor shall ensure metadata is delivered with the file to which it is related and will reference the filename or other identifying features (e.g. timestamp).

The Contractor shall apply the International Standards Organization (ISO) 10303-233, Industrial automation systems and integration - Product data representation and exchange - Part 233: Application protocol: Systems engineering, as a foundation for defining common program metadata.

The Contractor shall apply the International Standards Organization (ISO) 10303-239, Industrial automation systems and integration - Product data representation and exchange - Part 239: Application protocol: Product life cycle support, for common systems engineering metadata.

The Contractor shall ensure metadata used during a program phase is defined 90 days prior to its first use.

5.6 Data Transmittal

Data will be transmitted to NASA via one of the options in sections 5.6.1 through 5.6.5, as defined in each data requirements description and RFP/SOW.

5.6.1 View Data in Contractor System

The Contractor shall support viewing data within the Contractor's electronic system in a format readable by a standard Government workstation or otherwise approved by NASA. This action will be deemed as a delivery of data in-place, and such data will be maintained within the Contractor's system.

5.6.2 Direct Entry to NASA System

The Contractor shall include direct user entry of data into a NASA-owned system, including fields, values, or other information as required by the NASA system.

5.6.3 Upload to NASA File Repository

The Contractor shall include uploading files, whether document-formatted data, or structured data (e.g. SQL output), and filling any associated data as defined by the required formats (above) and the file repository, including Center, project, or other repository as specified in the data requirements descriptions.

5.6.4 System-to-System Connection

The Contractor shall provide an automated capability to pass computer-readable data between a Contractor and NASA system and across Contractor and Agency firewalls, via one of several mechanisms, including:

a. Restful Application Programming Interface (API) or Web APIs (interface defined mutually by NASA and Contractor).

b. APIs supported by middleware, e.g. SOAP API.

c. Fully documented standards-based API supported by Contractor tools to be approved by NASA.

5.6.5 Secured Transmittal

The Contractor shall encrypt sensitive information during transmission.

The Contractor shall utilize the Government standards (NIST 800 Series Publications) to meet data encryption requirements.

5.7 Viewing Data

In case of data stored in the Contractor systems, the Contractor shall provide online access/search to the data.

5.7.1 Search

Each Offeror/Contractor must respond/provide search criteria as stated in the SOW. Examples are:

a. The Contractor shall provide a public search capability that allows external visitors to search across all publicly available NASA Web content.

b. The Contractor shall prevent public search users from gaining access to access-controlled content.

c. Keyword-based search, similar to Web-based search engines like Google™, shall retrieve the term entered where found among the metadata and unpackaged data.

d. The Contractor shall ensure the following search functions are available [choose as required]:

(1) The system search function shall support the use of wild cards, case sensitivity selection, and phrase definition (i.e. the use of quotations around multi-word phrases to specify that the words in the phrase collectively constitute a single search term).
(2) The system shall support the use of Boolean operators (AND, OR, NOT) to allow the user to search based on multiple criteria.
(3) The system shall index and return the contents of attached text-searchable documents (based on the indexers available for various document types).
(4) The system shall provide a field-based filter that returns all the records that contain the value(s) in only that field.
(5) The filter shall support searching for multiple values in a single field (e.g. part number = #X AND #Y) as well as multiple fields (title contains "ding" AND part number = #X AND #Y).

e. All the metadata fields listed in section [State Section] of this document shall be available as criteria for filtering.

f. Search performance shall be sufficiently high to return search results within [Insert Number] seconds after a query is submitted.

g. If a complete search results set cannot be returned within [Insert Number] seconds, the system shall present results as they become available.

h. Results for a keyword (or key phrase) search shall provide context related for each result, including the name of the item, record, document, or package where the keyword was found, the date last modified, the field or section where the keyword was found, and up to 25 words of text that immediately surround the keyword.

i. The system shall suggest correct spellings or other probable search terms when a common typographical error or misspelling appears in a keyword search.

j. Search results shall be restricted based on permissions within user profiles. If the user has insufficient permissions to see a search result, the system shall provide sufficient feedback (e.g. “access restricted to Jan 1, 2006 problem on X subsystem”) so the user can request permission to view the data.

k. The system shall allow users to store search queries (e.g. data on X subsystem, of Y severity, between dates A and B, etc.) so that a query may be built once, stored, and reused.

5.7.2 Browsing and Navigation

The Contractor shall ensure the following browsing and navigation criteria [choose as required]:

a. The system shall allow users to browse the Data Archive/Repository.

b. The browsing interface shall support sorting and filtering based on metadata content and the time/date of uploads or downloads.

c. The system shall allow users to select particular files or metadata for detailed viewing within the system.

d. The system shall allow users to view the content of files, packages, or metadata in a Web browser.

[State other requirements.]

5.7.3 Viewing and Archiving Data

The Contractor shall ensure the following viewing and archiving criteria [choose as required]:

a. The system shall allow users to construct new data packages (integrated data views) by assembling files that reside in the Acceptance Data Package (ADP) Data Archive/Repository.

b. The system shall allow users to create a “snapshot” of a data package that can be retrieved later and will act as a historical record of how the data in that package appeared at the time the snapshot was created.

c. Archived data packages shall include additional metadata that specify the time/date of archival and the identity of the user who created the archived package.

d. The system shall allow for the control of access to data files and packages dependent on user profile information (see section [State Section].

e. The system shall allow provider personnel to upload data files and packages to the system without making those files and packages visible or accessible to any user outside the provider's organization.

f. The system shall provide configurable workflow support for provider approval processes that employ electronic notifications and digital signatures.

g. The system shall allow provider personnel to change the visibility and accessibility of their own uploaded data files and packages such that, once approved by the provider, users outside the provider organization (i.e. NASA personnel) may view and access those files and packages.

h. The system shall prevent provider personnel from restricting access to data files and packages once they have been approved by the provider and released to NASA unless NASA personnel give explicit approval (e.g. one or more digital signatures) concurring with such restrictions.

i. Once a user has created a data package, the system shall support sharing that package with other users who have the required access based on their user profile information.

[State other requirements.]

5.8 Stored Data

The Contractor shall ensure the following stored data requirements [choose as required]:

a. The system shall allow users to specify, construct, and store Technical Data Packages (TDPs).

b. The system shall explicitly tag, label, or otherwise represent with metadata or data that a package is a TDP, not an ADP.

c. The system shall treat TDPs as static, historical documents.

d. Each TDP shall include metadata requirements as described in this document.

e. Each TDP shall include metadata specifying the time and date of creation, the user who created the package, and the criteria used to construct the package.

[State other requirements.]

5.9 Technical Data Package Definitions

The Contractor shall allow users to store the criteria used to construct a TDP without saving the particular content of the TDP. That is, the system shall allow users to specify a “view” of data that is dynamically updated each time it is invoked.

5.9.1 Unpackaged Data

The system shall allow users to store data files that are associated with no particular data package.

Each data file shall conform to the data format requirements described below: [State Requirements.]

Each data file shall include metadata described below: [State Requirements.]

5.10 Workflow and Notifications

5.10.1 Notifications

The Contractor shall ensure a notification system exists to provide users with updates either based on their affiliation/role (e.g. contact for responsible organization) or user data (e.g. Jane Smith) as described in the section on user profiles [choose as required]:

a. The system shall allow notifications to be sent based on a variety of triggering events. For example, requests for action (e.g. review of an ADP or file is requested, etc.), status changes (e.g. a new ADP or ADP component is delivered), and other events might trigger system-generated notifications or emails to users.

b. Notification shall be available in both an automated (e.g. system sends notification when action item is created) and user-initiated manner (e.g. a user requests a signature and an email is sent to inform another user of the request).

c. The system shall provide the capability to notify users via email.

d. Defaults shall be provided for both time-based (e.g. X hours before an action is due) and activity-based (e.g. when a user has marked an action complete) notification triggers that are modifiable by the system administrator.

e. Users shall have the capability to modify their configuration of time-based and activity-based notification triggers within their personal settings attached to their user profile.

5.10.2 Digital Signatures

The Contractor shall ensure the following digital signature criteria [choose as required]:

a. The system shall include digital signature authority, and that authority will be based on roles specified in the user profile (e.g. only certain classes of users can submit an ADP for NASA review/approval).

b. The system shall provide the capability for users to request digital signatures of specific individuals or roles within the system.

5.10.3 Change Log

The Contractor shall ensure the following change log criteria [choose as required]:

a. The system shall log information about changes or updates to the data in the system (uploads or downloads of data or metadata, archival of data packages or package definitions, drops of data to the dropbox) by user and time stamp at the level of the individual field for metadata and at the level of data files otherwise.

b. Change log information shall include all workflow data (requests for signatures, signatures, etc.).

c. The system shall support authorized Internet access initiated from any off-site data provider, any NASA Center, and/or inquiries from any authorized source location (e.g. an authorized user's home workstation).

5.11 Administration and Other System Functions

The Contractor shall ensure administration and other system functions [choose from sections 5.11.1 through 5.11.3 as required].

5.11.1 Administration

The system shall provide an interface that allows metadata schema modification by a system administrator and is abstracted above the code level.

The interface for metadata schema modification shall be textual and appropriate for use by a system administrator using a text or XML-type editor.

The system shall provide an interface that allows a system administrator to specify and modify workflow requirements (e.g. required signatures).

The system shall provide an interface that allows a system administrator to create, modify, and delete user accounts, including user profile information as described in section [State Section].

The system shall provide an interface that allows an administrator to create, modify, and delete sets of field-relevant information over time (e.g. update the values available in drop-down menus for metadata collection).

The system shall provide an interface that allows an administrator to create, modify, and delete user groups.

The system shall allow an administrator to create, modify, and delete permissions, customizations, and access to the system and system data and metadata for user groups.

The system shall allow an administrator to create logical relations among groups (e.g. to relate groups hierarchically, to declare that user groups are mutually exclusive.

5.11.2 User Profile Data

User profile data shall contain the user's full name, username, affiliation data, role data, and customization data as described below:

a. Usernames shall be unique identifiers that may link users to system actions or to workflow elements such as action items assigned or signatures pending.

b. Affiliation data shall include employer and organization code (where applicable).

c. Role data shall include the user's title or position and the user's level of signatory authority as described in the digital approval authority requirements in section 5.10.2 to facilitate workflow management.

d. Customization data shall include modifications the user has made to system settings/defaults, which may include functions that vary widely from stored search queries to user interface settings.

e. Permissions rules shall apply to information access based on user profile data to determine:

(1) The accessible data set (e.g. X project only or Contractor A sees NASA data only but not Contractor B's data), and
(2) The type/level of access (e.g. read only versus write).

f. Users shall be able to control customization data directly within the system through their settings.

g. User profile data shall include information about the user groups [state section] to which the user belongs.

5.11.3 Authentication and Security

A single login and password shall be used for access to all components of the ADP system. In cases where the system links to data in external systems (e.g. as described in section 5.12 on integration with external systems), a second authentication/login will not be required where possible.

The system shall not allow users to perform any actions anonymously or in another user's name. This shall apply to all levels of access, including system administrators with the most broadly defined permissions.

Authentication shall engage the customized features outlined in section [State Section] on user profile data.

All authentication information shall be passed using a minimum of 256-bit encryption.

All data being sent over networks not controlled by NASA shall be encrypted to protect against data theft during transmission.

The system shall be capable of blocking access to data and metadata based on user profile information.

The system shall allow data and metadata to be defined as modifiable only by certain groups or individuals. These restrictions shall be managed through use of user profile data in section [State Section].

5.12 Integration with Other Information Systems

The Contractor shall ensure integration with other information systems [choose from sections 5.12.1 through 5.12.3 as required].

5.12.1 Data Decomposition

The system shall provide the capability to decompose an ADP or TDP into its component data files and to operate on those files independently of one another in service of building new packages, transferring data to [Identify Name] systems, or delivering data back to an ADP provider.

5.12.2 Transfer of Data to [Identify Name] Systems

The system shall provide the capability to transfer/route any TDP or unpackaged data file to the appropriate [Identify Name] data source(s) or system(s).

The system shall decompose TDPs into their constituent unpackaged data files prior to routing.

The system shall allow an administrator to specify rules or information required for routing to [Identify Name] data sources. For example, an administrator would be able to write a rule that says, "If metadata field F has value V, then route the associated data to system S."

The system shall allow an administrator to add, update, and delete information required for routing to [Identify Name] data sources.

The system shall allow an administrator to add, update, and delete any special data format requirements needed to enable routing to [Identify Name] data sources.

The system shall allow an administrator to update, alter, add, and remove any special data format requirements needed to enable routing to [Identify Name] data sources.

When no electronic link with a [Identify Name] data source is available/possible, the system shall provide the capability to send email or other notification to a point of contact for the unavailable data source so that a person may assist with the transfer/routing of data into that data source.

5.12.3 Retrieval of Current Data from [Identify Name] Systems

The system shall allow users to retrieve current data from [Identify Name] Information Systems.

The system shall distinguish Contractor-submitted data from NASA-generated data.

The system shall store data retrieved from [Identify Name] Information Systems in the Data Archive/Repository as unpackaged data as stated in section [State Section] only when one or more of the following conditions are met:

a. Those data are part of a TDP, and not otherwise.

b. Those data belong in a [Identify Name] Information System that is unavailable (i.e. not integrated with the ADP system).

Whenever the system displays data to the user that were retrieved from a [Identify Name] Information System, the system shall provide a clear visual indication of the time and date that the displayed data were retrieved.

Whenever the system displays data to the user that were retrieved from a [Identify Name] Information System that uses a version control scheme other than the time and date stamping, the system shall provide a clear visual indication of the version or revision of the displayed data.

5.13 Non-Functional Requirements

The Contractor shall ensure the following non-functional requirements exist when the data is stored in Contractor systems [choose from sections 5.13.1 through 5.13.8 as required].

5.13.1 Availability

The system shall be available at least 99 percent of the time on a 24-hour, 7-day-per-week basis. This includes planned outages associated with maintenance or software updates. This does not protect against an individual Center or an individual user losing access because of power loss, network failure, or other outages.

Planned outages shall be scheduled with agreement from the system administrator to ensure that they do not coincide with peak usage times (e.g. when hardware is being delivered and accepted ahead of integration testing).

All functionality shall be available to authorized users on any authorized computer that has the necessary software (an acceptable Web browser).

The server environment shall provide one of the following:

a. Backup server(s) that are physically and electronically separate from the primary server(s) to take the load if there are problems with the primary server(s).

b. Spare server that can replace part or all of the primary server to take over the full load of the system.

5.13.2 Flexibility

Software shall employ standardized abstraction layers in connections to any database, data repository, data warehouse, or other storage structure.

The system shall not rely on commands or code specific to any single database, data repository, data warehouse, or other storage structure.

5.13.3 Software Integration

The following elements have to be replaceable and updatable with no update to the software code of the rest of the elements:

a. Database technology.
b. Applications software.
c. Data integration layers.

Any changes to the communication specifications used to connect software elements must be approved by all applications that use them, and agreements shall be reached to ensure any needed changes to individual systems are made in time.

5.13.4 Platforms

The system shall be compatible with the operating systems specified as Agency standards in NASA-STD-2804, Minimum Interoperability Software Suite (i.e. no functionality will be restricted or unavailable to users of any of the standard operating systems).

5.13.5 Security

The required security level for the system shall be determined using the criteria defined in NIST SP 800-60, Guide for Mapping Types of Information and Information Systems to Security Categories.

The system shall comply with the requirements set forth in NPD 2810.1 and NPR 2810.1, Security of Information Technology.

The system shall be tested against security controls for the defined security level as mandated by NIST SP 800-53, VI & VII, Recommended Security Controls for Federal Information Systems.

5.13.6 Network

Rules for allowable connections to the system shall be maintained by system administrators to ensure that the proper balance between security and access to data is maintained.

The system shall be able to block specified services if the user's network connection is deemed insecure.

All servers shall be protected by a firewall allowing access only to the ports used by the ADP system and its approved sibling applications.

The firewall shall also use allowed Internet protocol (IP) lists for ports that are specifically opened to connecting servers together.

The system shall be capable of encrypting data up to 256 bits.

5.13.7 Integrity

All data and related software shall be automatically backed up daily with a minimum of 1 month of roll-back capability.

All backups shall be stored on two distinct types of media (e.g. hard drive and tape).

5.13.8 Scalability

The system shall accommodate up to [Insert Number] concurrent users (estimate based on percentage of total [Insert Number] users).

The system shall support on the order of [Insert Number] user accounts (estimate based on number of users per Contractor by number of primes plus percentage of NASA personnel).

The system shall store and process on the order of [State Number] terabytes of data and metadata combined (estimate based on average file size by number of files).

6. Conclusion

A NASA-wide policy or standardized approach for ensuring data integrity, access, and successful transfer does not currently exist as practices. It varies across the Agency. The team did find instances where policies are currently in place or in work and fully acknowledges the flexibility of each individual program, project, or contract to tailor. In the absence of a NASA-wide policy, contracts should ensure contract language exists to identify and review data acquisition requirements and, in particular, the rights the Government should have in using the delivered data for the full program. This must be done as early as possible in project planning to establish an integrated set of data requirements. The requirement to deliver and manage data in a digital environment influences the manner in which data delivery requirements are levied on existing and future contracts. Ongoing contracts should consider contract modifications to require the delivery and management of contractually delivered data in a digital environment on contracts that do not currently require data delivery in a digital format.

NASA should acquire only the essential Contractor-originated data required to meet all program life-cycle requirements. Every attempt should be made to integrate all functional specialties, e.g. safety, reliability, quality, logistics, test, verification, etc., to minimize data acquisition redundancies and inconsistencies. This integrated effort must include sub-projects within the various programs.

For ongoing NASA Earth science contracts, continue to use the following guidance:

a. NASA will plan and follow data acquisition policies that ensure the collection of long-term data sets needed to satisfy the research requirements of NASA's Earth science program.

b. NASA commits to the full and open sharing of Earth science data obtained from NASA Earth-observing satellites, sub-orbital platforms, and field campaigns with all users as soon as such data become available.

c. There will be no period of exclusive access to NASA Earth science data. Following a post-launch checkout period, all data will be made available to the user community. Any variation in access will result solely from user capability, equipment, and connectivity.

d. NASA will make available all NASA-generated standard products along with the source code for algorithm software, coefficients, and ancillary data used to generate these products.

e. All NASA Earth science missions, projects, grants, and cooperative agreements shall include data management plans to facilitate the implementation of these data principles.

f. NASA will enforce a principle of non-discriminatory data access so that all users will be treated equally. For data products supplied from an international partner or another agency, NASA will restrict access only to the extent required by the appropriate Memorandum of Understanding (MOU).

APPENDIX C

MODEL-BASED DATA DEFINITION

C.1 PURPOSE

NASA engineering and partners use models defined through model-based data definition as part of model-based enterprise (MBE). This NASA Technical Handbook provides a means for consistent model-based data definition, direction, and execution supporting model-based acquisition methods, practices, and protocols as defined and utilized per program and Center definition.

MBE is an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the life cycle.

Model-based engineering and definition have multiple meanings to many people, and the intent of this Appendix is to identify and define the elements of MBE that are impacted and driven by the program DRD.

To provide a common baseline of definition and guidelines, the following sections discuss not only the premise of the description but also a definition as provided by the National Institute of Standards and Technology, NASA, and commercial companies doing business with NASA.

C.2 MODEL-BASED DATA DEFINITION

Model-based data definition is a subset and critical element of MBE and is intended to increase the probability of mission success by increasing the availability, effectiveness, integrity, fidelity, and efficiency of model data and data interchange/integration across like as well as disparate systems. The end goal of data definition is to provide and improve the **availability of the right data to the right people at the right time, thereby reducing risk**.

The process for the management of technical data (models) is required by NPR 7123.1 for ensuring that the digital data required are captured, stored, version controlled and managed, data integrity is maintained, and data dissemination processes and data definition and integrity meet contracted requirements.

Within the MBE framework, model-based data definition defines not only the context of the data definition but also the management of product data as it is defined for use (Process). It enables informed decision making across the product development cycle and applies a consistent set of business solutions that support MBE elements such as MBSE, model-based manufacturing (MBM), model-based inspection (MBI) (utilizing CAD for CMM inspections).

Model-based data definition:

a. Enables process optimization and maturity using MBE as a baseline and establishes a paradigm to help NASA programs achieve the highest level of collaboration, interoperability, efficiency, and data availability. The implementation of a fully digital MBE environment is necessary to comply with the program requirements.

b. Defines and enables technological requirements, whereas IT systems across NASA need to be made interoperable or integrated to the extent needed to provide a secure, readily accessible environment to enable required collaborative MBE capabilities.

c. Is the underlying architecture required to tie data and processes together and provides the framework for collaboration and interoperability. MBSE is the systems engineering subset of MBE.

d. Provides the foundation and capability to orchestrate procedural events such as design reviews from authoritative data sources.

Table 4, Example Products in the MBE Environment, provides products expected in Pre-Phase A through Phase F.

Table 4—Example Products/Activities in an MBE Environment

Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
Concept Studies	**Concept & Technical Development**	**Preliminary Design**	**Final Design & Fabrication**	**Assembly, Test, & Launch**	**Operations & Sustainment**	**Closeout**
Conceptual systems, behavioral and descriptive models and simulations, especially MBSE Cost estimation	Functional and non-functional requirements Functional flows MBSE and MBD models, including analysis and simulations	CAD designs MB(x) models, including failure modes analysis Prototype test data Refined costs MBSE/MBE models and simulations	MBSE/MBE models and simulations MBD – GD&T, PMI Inspection data Change orders Effectivities	Integration Models & simulations Verification Certification Change orders Effectivities	Operations Anomalies Simulations Science data Change orders Effectivities	Commissioning simulations Data archiving Final costs

Architecture, infrastructure, and data definition are at the core of this framework on which all collaboration (Center to Center and Center to prime/partner), workflows, data management, and data sharing will be built.

Additionally, MBE elements to be considered and included in the data definition or the DRD are NOT restricted to only CAD models and may also include many of the MB(x) definitions listed in Appendix D.

It is imperative that all parties as defined in the DRD take notice to the consistency of definition and follow NASA policies and standards to ensure compliance.

Notable elements for focus during data definition are discussed in sections C.3 through C.15 in this Appendix. See Appendix G for use cases for establishing MBE elements and interoperability requirements.

C.3 "SYSTEM MODELS" VIA MODEL-BASED SYSTEMS ENGINEERING (MBSE)

MBSE is a method to drive *system models* that represent functions, requirements, and conceptual systems and is present and interactive within the life cycle (concept definition through retirement). The intent of MBSE is to facilitate traditional systems engineering resulting in enhanced communications, specification and design, system design integration, and reuse of system artifacts and models. MBSE can support both engineering data and business data.

In MBSE definition and engineering, a system model is at the center of the developmental process, from requirements development, through design, implementation, and testing. The model is a specification that is continually refined throughout the development process. After model development, simulation shows whether the model works correctly.

It is expected that in the MBE environment, MBSE will extend to domains to support complex predictive and effects-based modeling that include integration of engineering models with scientific and phenomenology models; social, economic, and political models; and human behavioral models[10].

While the output of MBSE is an analytical system model, it is sometimes developed in SysML™. In an MBE environment, MBSE is a key critical success factor in that it helps teams

[10] MBSE State of Practice - 2020. Presented at the INCOSE 2007 Symposium. http://www.incose.org/enchantment/docs/07docs/07jul_4mbseroadmap.pdf (accessible to INCOSE members only)

focus thinking to develop engineering work products. MBSE captures the decisions, performs analyses, and produces review and audit materials.

An MBSE system model can incorporate other abstract models to document design sets and graphical presentations of process flows that enable group participation in concurrent engineering. This includes CAD models, digital manufacturing models, as-built models, model-based testing, and logistics functions. MBSE provides the capability for these reviews to be conducted with a single-source interconnection model that provides viewing of the system models and their interactions from different perspectives (i.e. discipline-dependent views).

All uses of the MBSE artifacts must be clearly defined per program and defined in the program DRD.

C.4 Requirements

The size (scope and scale) of a program/project has an impact on the MBE environment and solution but is not deterministic in regard to requirements for managing product data. Factors such as the nature of the mission; mission class; the amount and types of data; data acquisition; sensitivity; retention needs; the location, timing, and duration of data access; and the organizational relationships of participants are important for characterizing the demands that programs/projects make on expected MBE capabilities.

Requirements management in a model-based program/project environment provides a framework for defining, refining, documenting, and maintaining the requirements of the product(s) produced by the program/project. The requirements are to be maintained and managed throughout the entire life cycle of the project.

Program/project requirements are defined and documented by the program/project's systems engineering and integration functions, or their designees, and documented in the Systems Engineering Management Plan in accordance with NPR 7123.1.

Requirements should be defined in the DRD and:

- Allocate requirements to various program/project organizations for decomposition.
- Define the relationship of requirements to other information in the MBE environment.
- Provide the framework for requirement derivation and a scheme for parent and child requirement relationships.
- Provide links for access to authoritative requirement information.
- Allow the definition and management of detailed information attached to the requirement such as margins, technology readiness levels, risks, and cost data.
- Be traceable to its source, downstream to its implementing product component, and to their verification and validation activity.

- Be securely controlled and traceable from beginning to end of life (history and use).
- Be captured in a virtual database that provides secure but easy access. Requirements management tools should provide automatic notification of requirement changes and impact to flow-down or linked requirements.

C.5 COMPUTER-AIDED DESIGN (CAD) DATA (MECHANICAL CAD [MCAD]/ELECTRICAL CAD [ECAD]/COMPUTER-AIDED ENGINEERING [CAE]/COMPUTER-AIDED MANUFACTURING [CAM])

Effective CAD data management enables immediate access to needed PDD but must define relationships between all associated CAD parts and assemblies. CAD management of MCAD, ECAD, and CAM parts and assemblies have to include management of systems and software across the entire program/project life cycle.

Items to be considered and resolved within the definition of the DRD should address and take into consideration problems seen and occurring with managing CAD data because:

a. Incomplete information causes iterations—not all CAD objects come with CAD data packages.

b. CAD naming conflicts—may have multiple names for the same parts.

c. Change management—lack of governance needed and defined with approval, as names may change—no way to see if it is the same geometry.

d. Data conversion—CAD drawings are converted to a defined standard for consistency (see Appendix F).

e. Broken CAD links when moved manually—links and relationships are broken losing traceability.

f. Inconsistent CAD and model version/revision controlled.

g. Inconsistent modeling standards.

h. No design intent captured or shared.

Programs/projects should work to define, agree with, and implement a CAD data management environment in which:

a. MCAD (parts and assembly) models and associated data are captured in a virtual and accessible database.

b. Relationships between all associated MCAD parts and assemblies are defined.

c. Ability to rename to-be-determined (TBD) items prior to release into MBE exists, or if late, fall under a change control board for traceability.

d. Structured check-in/checkout process and revision control ensure data integrity.

e. Workflow and automatic notification capabilities enable adoption of product development best practices.

f. ECAD and systems (parts, files, and assembly) data are available through a virtual database.

C.6 Part Manufacturing Information (PMI)

The mechanical properties and design for manufacturing instructions of a product (for example, digital mock-up (DMU), digital computer-aided test model) and PMI have to be properly examined and checked for content, context, and maturity. This can involve checking the overall geometry with regard to dimensions and shape, interference checks, and collision checks for assembly and disassembly, as well as design space checks.

For these purposes, the geometry, product structure, and metadata are displayed and analyzed in a DMU application; however, results are captured in the model data definition. A distinction is made between static and dynamic DMU analysis. In the case of static DMU, an examination of the static parts is performed. In the case of dynamic DMU, the dynamic parts or assemblies are examined.

While visualization is critical to convey design intent and analyze form and fit, information used to drive manufacturing (PMI) and assembly is also critical. DMU is an excellent source of information and graphics to enable and provide quality instruction downstream. Tracking and capture of this information is equally important and has to be defined as a critical path item in the DRD.

As a rule, a simplified, tessellated representation of the envelope geometry is usually sufficient for use in DMU. In the case of measurements, however, it should be noted that the level of tessellation accuracy always must be higher than the required measuring accuracy.

The most important items to consider are:

- The availability of applications that support the respective required DMU functionality (e.g. assembly checks and collision control).
- Use of models from different source systems (multi-CAD).
- High-quality examination of large assemblies.
- Transferability of kinematics from the original model to the target model for dynamic DMU analysis.
- Development of a TDP from which other Centers, partners/primes, and suppliers can derive design intent to properly manufacture the product.

C.7 Modeling and Simulation (M&S)

Results from M&S are rich data used daily for making critical decisions in design, development, manufacturing, ground operations, and flight operations. The program/project manager and delegated Technical Authority(s) have the responsibility for ensuring the credibility of the results from these M&S activities (reference NASA-STD-7009, Standard for Models and Simulations and NASA-HDBK-7009, NASA Handbook for Models and Simulations: An Implementation Guide for NASA-STD-7009). Models and resulting simulations fall under the governance of the DRD to ensure all parties are working with the latest, common data.

Confidence in M&S results is achieved by:

a. Identification of best practices to ensure that knowledge of operations is captured in the user interfaces (e.g. users are not able to enter parameters that are out of bounds).

b. Development of processes for tool verification and validation, certification, re-verification, revalidation, and recertification based on operational data and trending.

c. Development/identification of standards for documentation, CDM, and quality assurance.

d. Identification of any training or certification requirements to ensure proper operational capabilities.

e. Development/identification of a plan for tool management, maintenance, and obsolescence consistent with modeling/simulation environments and the aging or changing of the modeled platform or system.

f. Development of a process for user feedback when results appear unrealistic or defy explanation.

g. Development of a standard method to assess the credibility of M&S presented to the decision maker when making critical decisions (i.e. decisions that affect human safety or mission success) using results from M&S.

h. Assurance that the credibility of M&S meets the project requirements, and the appropriate documentation is captured and preserved.

i. Reinforced verification and validation (V&V) models and practice.

C.8 Document Management

Documents such as specifications, policies, and test results (other than CAD and systems models) provide an important communication medium using prose. This facilitates a broad communication of program information to a broad set of engineering and business backgrounds. MBE is evolving to be the source of the document production, where documents are communication methods and the models are the authoritative source.

C.9 Documentation and Archiving

For the purpose of documenting and archiving engineering data, it is normally necessary to factor in exact data representation, including all metadata and PMI. The DRD must be prolific throughout the life cycles but also needs to define consistency and accessibility even after design is complete.

The latter is especially important with regard to product approval and product documentation if drawings and technical documents are being replaced by digital 3D models. Compliance requirements often need to be satisfied.

The most important requirement relating to the documentation and archiving of engineering data is that all relevant information be stored in a format that can be read irrespective of a specific IT infrastructure and after a long period of time; in the aerospace industry, for example, the Long Term Archiving and Retrieval (LOTAR) activity (http://www.lotar-international.org/lotar-standard.html) addresses archiving of data for long life-cycle programs.

The most important items to consider are:

a. Ensuring proper consideration is given to all product data.

b. Ensuring problem-free combination of data from different source systems.

c. Ensuring that the data can be accessed even after long periods of time (standardized format).

C.10 Portable Product Life-Cycle Management (PLM) Document

In modern product development processes, the utilization of 3D information does not end in the engineering department. Integrated product development (sometimes referred to as concurrent engineering) requires that departments/functions such as purchasing, quality assurance, technical documentation, configuration management, planning, manufacturing, operations, maintenance, and sustaining also have to be able to access 3D information in combination with a wide variety of different documents such as bids and requests for quotes, quality control checklists, technical and manufacturing documentation, etc.

It is important that the program DRD owns this responsibility and ensures that this content can be combined in a multimedia container that includes all the information and can also be used offline.

The most important items to consider are:

a. Information in the form of 3D data, metadata such as 2D representation, text data, and binary data can be combined in a single file and can be managed there.

b. The data can be combined easily with information from various source systems.

c. Comprehensive control options for file access (intellectual property protection) exist.

d. Easy-to-use, cross-system viewers are available**.**

C.11 Configuration and Data Management (CDM)

CM in the model-based environment provides the structured environment with a framework for programs/projects to develop and control their requirements and associated engineering products and information, providing a system to reconcile and enforce accountability between various bills of material (BOMs) covering several configurations and restructuring use cases such as BOM splits, merge, substitutes, change action propagation, etc.

The CDM structured environment must address and define the following:

a. Functional and performance characteristics of the program/project’s products.

b. Functional, allocated, and product baselines.

c. Requirements for the design, manufacturing, testing, checkout, training, maintenance, operations, sustaining, and disposal of the products.

d. Verification that the end product is in compliance with the requirements and associated information.

e. Traceability of waiver, deviation, and non-compliance of requirements information.

f. Retention, security, and data integrity of records.

g. The determined level of CM by supporting organizations.

The program/project-level CDM processes need to flow down to establish and maintain consistency of multi-level supplier organizations' products with requirements through the entire program/project life cycle via the MBE environment.

CM creates a consistent and systematic method for products delivered to the programs/projects that:

a. Identify the product configuration (architecture, current status, and related information) at KDPs and other times.

b. Systematically control changes to the product configuration.

c. Maintain the integrity and traceability of the product configuration throughout the product life cycle (for example, operations anomaly functions may require fast access to information from the earliest product phases).

d. Preserve and retire product records throughout the product life cycle to be defined in NPR 1441.1, NASA Records Management Program Requirements.

The CM administrative function defined in SAE EIA-649-2 shows how the product data is to be released. Once data has been released, it follows the structured procedures and processes established by the program/project's CDM and MBE Plans.

The program/project manager and delegated Technical Authority(s) define and document as part of the MBE Plan what product data are released, when that product data are to be released, events that necessitate product data change, and the processes that provide the visibility of the product data configuration life cycle for internally and externally produced product data.

C.12 Bills of Material (BOM) Product Breakdown Structure

A product breakdown structure is a hierarchical program/project view of the relationships of the hardware and software products and component products. Product structure provides a platform on which an entire program/project product family can be based. Product structure involves decomposition of the overall functionality of a product into a set of defined functions, the component parts of the product that provide those functions, and the specification of the interface between the components—how components interact together in the product as a system. It is a product data structure that captures the end products, its assemblies, their quantities, and relationships.

A BOM is a functionally dependent view of a subset of the product structure that includes the physical items and is a formally structured list for an object (semi-finished or finished product) that lists all the component parts of the object with the name, reference number, quantity, and unit of measure of each component. MBE should provide for traceable documentation of all changes to the BOM, including when and why it was changed, which documentation implemented the change, who approved the changes, and the disposition of the affected items.

Problems occur with the development and use of BOMs because:

a. Only the “as-designed” BOM is managed in engineering.

b. The proposal BOM is created, then not carried forward.

c. Not all data delivered are related to part definition.

d. No product structure is delivered.

e. Effectivity for BOM change is limited to a single change and by date only; most recent is all that is saved.

f. Substitutes and alternatives are managed as separate BOMs and products.

Programs/projects should work to define and implement a product structure and BOM development that can:

a. Manage product structure and BOM data.

b. Capture and manage substitutes and alternative parts.

c. Provide revision control and history of product (BOM) data.

d. Manage multiple views of the BOM, including as proposed, as designed, as built, and as launched.

e. Manage effectivity by event, date, lot, or serial number as necessary.

The product structure should be documented in the MBE Plan and provides a simple, concise view of the product that can be used as the central point of reference for all information describing and related to each element, subsystem, assembly, subassembly, and part comprised within the structure. The complete product breakdown structure segment list should be defined, including design data for an assembly and/or subassembly such as as-designed (Engineering or EBOM), as-built or as-manufactured (Manufacturing or MBOM), as manifested, as flown, and as disposed, beginning either at the highest level (system) or lowest level (component) to access all related data based on access privileges.

A good product structure should:

a. Be a decomposition/interrogation of the system into its parts.

b. Define the complete segment list, including design data for an assembly and/or subassembly such as:

(1) As designed—a product structure representing the configuration after release, before manufacturing is started.
(2) As built (as manufactured)—a product structure that represents the configuration as it has been manufactured and delivered to the NASA inventory.
(3) As manifested—a product structure representing a configuration designated for a specific flight.
(4) As flown—a product structure representing a configuration that has flown.
(5) As disposed—a product structure representing a configuration that has been decommissioned.

Provide the capability for an individual to start at the highest level (system) to access all related data (based on the individual's access privileges) by drilling down to the lowest component of the system, as well as walking up from the lowest component to the highest level, including, but not limited to, access to supporting design documents such as analysis reports, test reports, requirements, and V&V checklists.

Components include hardware, software, and configurable logic devices as shown in the examples below:

a. System.
b. Segment.
c. Element.
d. Subsystem.
e. Assembly.
f. Subassembly (component).

g. Part (piece part).

C.13 Engineering Release and Change Management

All engineering releases, changes, and supporting information are properly managed and the terminology of the engineering release process properly defined. The change process is to be a multi-level supplier, closed-loop process with changes automatically integrated, routed, and closed looped with the impacts of the change easily visible. A history of changes is to be maintained.

Program/project managers, delegated Technical Authorities, and appropriate engineering organizations consider engineering release of data that occurs during the following life-cycle states/phases as part of the development of MBE engineering release and change management:

a. Requirements definition.
b. Design and development.
c. Fabrication/manufacturing.
d. Test and verification.
e. Flight and operational data.

The term release (as a verb) is to authorize for dissemination a particular version of a product and/or product information that is made available for a specific purpose. The activities associated with the term "release" can change during these different life-cycle states/phases. For example, release of the design configuration makes available the set of design information, incrementally released to date, by the development activity for a product during a product's definition (development) phase.

The term "release" can be used in a given context to mean "you can do X with Y," where both X and Y vary. For example:

a. Released Upper Stage CAD model of Liquid Oxygen (LOX) tank (Yproduction) means the prime can start manufacturing (Xmake or buy).

b. Released trade study of material choices for Upper Stage LOX tank (Y') means designers can proceed with Upper Stage tank design work (X').

A data object is defined by the object itself, its metadata (including effectivity), and its state (e.g. "in work," "under review," "released"). Additional data are required to indicate how the data objects relate to other data (e.g. effectivity). A method for capturing the object and relational data is to be developed for usage, change control, and integration of its intended use (effectivity and authorized usage).

The object's type alone does not necessarily determine its usage without supporting metadata. For example, a CAD model can be released as:

a. Design definition model for manufacturing (e.g. Upper Stage LOX Tank Production Model release), or

b. Intended for use in outer mold line development.

Process details depend on both object type and intended use and are not exclusively defined by project phase, e.g. more design work is done in the detail design phase; but design work is also done in operations to support block changes and sustaining engineering. Object type and usage are considered along with project and product phases during process development.

The program/project has to have confidence that data in a given state means the same thing to everyone:

a. A process that produces a known object in a known state is to be provided. For example: Product definition package (3D CAD models, 2D drawings, and material specifications) "released for manufacturing" always means released for production activities such as manufacturing planning, computer-controlled manufacturing machine programming, procurement, inventory management, etc.

b. If work is distributed among Centers or multi-tiered suppliers, the program/project needs to assess what release means across context and ensure effective integration.

Different objects have different uses and users, and it is those use cases that should determine the meaning of the states (e.g. preliminary release-development use only):

a. MBE and CDM distinguish between types of objects and their intended/authorized usages. For example: Several external suppliers use two design paths: prototype and manufacturing; 3D CAD models that are released for prototyping are NOT released for manufacturing.

b. Within each use case and for each product data category (i.e. CAD, parts assembly, analysis, etc.), the program/project manager and delegated Technical Authority(s) define the life-cycle states (in work, approved, released, etc.).

The program/project manager, delegated Technical Authority(s), and engineering determine if some data needs special handling and what standards should be used or developed to address this data. Examples of these data objects/types are engineering models/design/analyses (e.g. SysML™, 3D CAD/CAE, etc.). Another data type, for example, could be MATLAB designs used for modeling of guidance, navigation, and control (GN&C) algorithms and then has source code auto-generated for integration into flight software.

System synchronization, the process of collecting a known set of configurations for a system-wide test at various points in the overall system life cycle, enables early integration testing, as well as early investigation of alternatives.

With large amounts of externally provided data, it is difficult for NASA programs/projects or the lead systems integrator, due to cost and other factors, to insist that suppliers (e.g. primes, partners) all follow a defined/specific process. For this case, the program/project can and should insist that processes have key states that map to defined program/project core states:

a. The MBE Plan should provide a mapping of source states to destination states that provides confidence that the data can and will be used for the intended purposes and not unintentionally misused. The MBE Plan should lay out clear contractual requirements using the contract's SOW/PWS and include DRDs utilizing standards such as MIL-STD-31000. (See Appendix A.) For example, an external supplier can call it "manufacturing release," one NASA Center can call it "final release," and another NASA Center can call it "engineering release," which will be inconsequential when delivered per DRD.

b. Source-to-destination mapping confirms that all these are the same as the program/project-defined "production release." Refer to Figure 2, Notional State Compatibility Map.

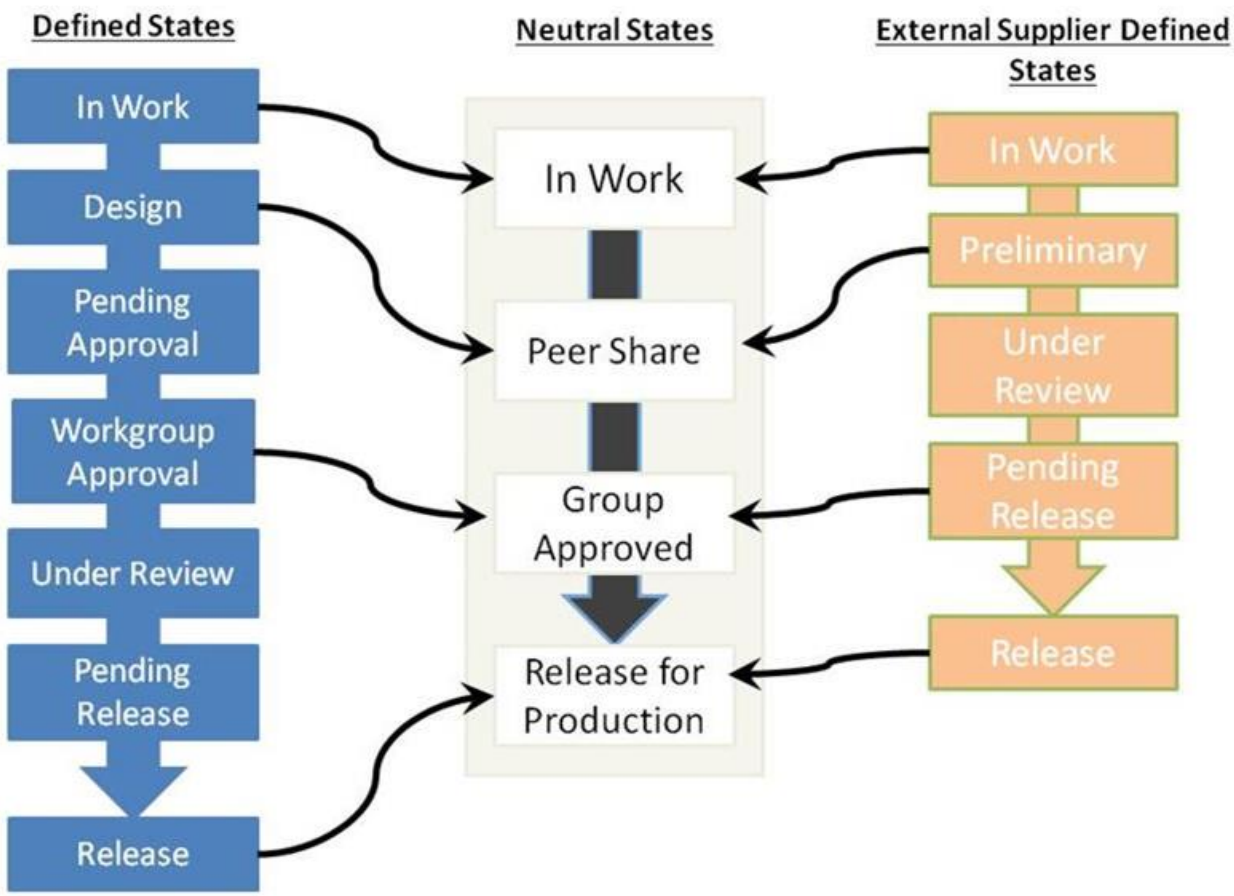


Figure 2—Notional State Compatibility Map

C.14 Parts and Library Management

Parts data handling is distributed across Centers and out to primes, assigned to multiple different functional areas within projects, and maintained within locally controlled design environments.

Effective handling of how parts are identified, defined, categorized, authorized, and specifically, how CAD data objects are handled in systems for design and sustaining engineering, are critical to performing the job of systems integrator and must be defined in the DRD.

When part numbers exist without exact specifications, or exist with a part number that is similar to the part number of another component, time and resources will be required at a critical point in product development to reconcile the discrepancy.

Part number proliferation causes confusion and duplication—not only duplication in effort but duplication in cost for maintaining parts inventory. Parts data handling processes should be defined upfront and should be enforced and followed for such matters as part naming and substitutes/alternatives.

Establishing parts libraries is critical in program/project development. Multiple libraries can exist such as part definition libraries, M&S libraries, and CAD libraries. Maintenance of these libraries can be spread across multiple organizations, internal or external to the program/project, and usage can be shared by many users across organizational boundaries. It is imperative that the programs/projects understand and document the library structure and ensure approved practices are established.

A CAD parts library functioning in an MBE environment provides an efficient and flexible framework for developing, promoting, using, and maintaining CAD common parts libraries, registries, catalogs, and associated support mechanisms. The description of these libraries, registries, catalogs, and databases may include terminology such as "standard," "preferred," and “electronic, electrical, and electromechanical (EEE).” The CAD functions supported by the libraries may include ECAD, MCAD, and CAM.

A CAD parts library’s functions should include the following:

a. Accommodate the use of multiple CAD common parts libraries by the organizations within the enterprise while requiring appropriate identification, naming, and usage; establish processes to minimize the number of duplicate labels for the same physical part.

b. Provide a mechanism for a CAD developer or integrator to determine if a part is already defined in a common library within the enterprise's MBE environment.

c. Establish rules and business processes to accept individual new part definitions and designations into the program/project's common parts catalog, registries, and naming conventions.

d. Establish rules and business processes to accept wholesale existing part definitions and designations (entire existing parts libraries) into the program/project's common parts catalog, registries, and naming conventions.

e. Establish security rules and business processes for access to CAD parts that are proprietary, intellectual property, or designated as SBU.

f. Establish and support audit and compliance functions to verify that naming conventions, configuration and data management, and data architecture requirements have been satisfied.

g. Establish rules and business procedures for external organizations that are not part of the program/project's MBE system to verify the uniqueness of proposed part names and enter new parts into the program/project's parts catalog system (delivery from an external source).

The scope of the CAD common parts library interoperability processes should be flexible. The business processes for the CAD common parts library interoperability should be defined in the program/project's CAD standards, CDM, and MBE documentation.

The DRD should describe how CAD standards will be applied over the program/project's life cycle, along with use of other internal or external standards, practices, settings, and supporting tools with responsible parties. The DRD should also identify the program/project data or documents that the CAD producer is to provide in addition to the CAD object to ensure full PDD such as parts lists, materials specifications, and acceptance testing specifications and where this material will be maintained.

C.15 Technology

MBE solutions should consider use of open architectures capable of supporting standards-defined interoperability to address new and changing requirements.

Critical items to be considered include:

a. Architecture: Common definition for data hierarchy and collaboration. Top down and bottom up links and relationships need to be considered and common across all program participants.

b. Designing and implementing technical solutions for MBE require resources and knowledge.

c. Even the simplest consolidation of users onto an existing system requires technical support for the creation of accounts and the transfer of data, user training, and coordination with customers, their managers, and the technical support team.

d. Consolidations that involve greater technical effort would require the creation of new objects and the redefinition in the new location (or partition of an existing implementation), in addition to the simplest consolidation.

MBE technology is often (but not solely) procured as a single integrated tool suite provided by a single vendor comprised of commercial database management systems; custom-written software; COTS interface tools; report writers; integration and utilities elements; and configuration, auditing, administration, and definition files.

While the value and economies of such a solution are evident, no one tool can accommodate all the needs in the heterogeneous environment present in many NASA programs/projects; and the evaluation and selection of the correct technology for MBE is critical. Therefore, a key critical success factor is the openness of the technology suite and standards-defined interoperability.

APPENDIX D

DIGITAL DATA COLLABORATION

D.1 PURPOSE

This Appendix provides guidance for digital data collaboration. Data through all life-cycle phases can cross many entities that will likely change over time. That data today is generally electronic, the design environment continues to move toward a models-based approach, and the engineering/acquisition processes are more automated and demand a highly collaborative/social workforce during all phases of the life cycle.

D.2 DATA INTEGRITY AND SECURITY

Data integrity during data acquisition continues to become more important to ensure the following MBE artifacts, which can also be characterized as model-based x (MBx), are considered, **where** “x” can and should include:

a. MBSE (model-based systems engineering)—design capture of logical, functional, and behavioral system models leading to physical elements such as schematics, analyses, and CAD.

b. MBD (model-based definitions) - annotated 3D CAD models of design which capture the physical system models leading to design definition and manufacturing elements such as geometric dimensioning and tolerancing (GD&T), PMI, etc.

c. MBE (model-based enterprise) – an organization that uses model-based engineering

d. MBe (model-based engineering) - an approach to product development, design, manufacturing, and life-cycle support that uses digital models to drive all engineering activities.

e. MBD (model-based definition)—design capture of schematics, analyses, CAD, ECAD, CAM, 3D scan, surveys, field measurements, simulations, etc.

f. MBM (model-based manufacturing and assembly)—as designed/as built.

g. MBI (model-based inspection, including quality/compliance/assurance)—assurance that the digital mode realized products meet defined maturity and content levels as consumed and acted upon utilizing their product manufacturing information (PMI).

An established data definition framework captured and reported in the DRD ensures the following:

- **Security:** All PDD is captured through a secure environment that meets the data's security requirements as defined by NPR 2810.1 regardless of the data's form (digital or hardcopy).
- **Product Data Integrity:** A single source of product definition where relationships between all associated product documents are defined and managed.
- **Automation:** Workflow and automatic notification capabilities are provided.

Note: This planned environment ensures that all product data (CAD and product documents) are captured and distributed per standard operating practice and are compliant with DRD definition.

- **Relationships** between models and all the associated CAD parts and product documents are defined and managed.
- **Data**, particularly CAD part numbers, are searchable by attributes and metadata.
- **Product data** are controlled as defined by contracts and data sensitivity and are securely shared as needed and when needed.

D.3 DRD Digital Data Standardization

The need was recognized for NASA to adopt industry standards and approaches for digital data interoperability to enable data interoperability and move beyond the storage of raw, uncorrelated data. The following sections contain the contract language and the associated standards necessary to execute digital data interoperability, which benefits NASA, its contractors, and partners. DRDs are provided in Appendix A as a starting point for Centers to define their specific needs.

Digital data deliveries have primarily been represented by digital scans of documents or in non-machine-readable PDF (scanned/raster format) and stored in a file system or content management system. This approach to data interoperability has fallen short in that data delivered as part of a page-formatted document lack the relevant context required to effectively leverage the data access and interoperability potential inherent to digital assets.

That is not to imply that exchanging digitalized data will solve the data interoperability problem. Even digital data replication from system to system presents problems without a computer-readable format that maintains the referential integrity of the data. As an example, experience has indicated that the manual replication of data from one application to another could typically create a discrepancy in 40 percent of the transferred data (refer to NIMA-RPT-004, Future Data Exchange for NASA Programs). The disposition of that amount of data, per transfer, increases the argument for standardization to bring about affordability and sustainability.

Proper data interoperability capability is achieved through the identification of IT standards and the application of contractual methods to ensure implementation and alleviate the data interoperability limitations that currently challenge NASA's programs/projects. Multiple options for data interoperability among NASA Centers and programs/projects with contractors, industry, partners, academia, services, and platforms exist. This section provides information to ensure that solution maturity is aligned with organizational requirements, proper data formats are applied, and data transmission types are understood. In addition, guidance on contract language is included to enable successful preparation of an RFP on data interoperability in Appendix B.

Digital data standardization provides:

a. Consistency of data and data use across systems.
b. Minimal redundant data collection and entry.
c. Maximum utilization of relevant technology.
d. Improved audit trail accessibility.
e. Rapid retrieval of the audit trail, enabling:

    (1) Better informed, real-time management decisions concerning changes.
    (2) Increased quality in CDM and control.
    (3) Support for effectiveness of analyses of metrics.
    (4) Improved data acquisition times.
    (5) Improved data review and integration for:

        A. Elimination or reduction of outdated or discrepant data copied into non-authoritative sources.
        B. Elimination of manual management of relationships between data.

MIL-STD-31000B, Technical Data Packages, defines the following:

a. Three-dimensional intelligent (3Di) technical data—a 3D viewable representation of an item provided in a widely available software format (e.g. ISO 32000-1, Document management — Portable document format — Part 1: PDF 1.7). This representation details the complete technical description of the required design configuration to include, but is not limited to, geometry, topology, relationships, tolerances, attributes, metadata, and other features necessary to define a component or assembly.

b. 3Di format—the standard arrangement and organization of information within a 3Di viewable representation of an item. This includes such features as the size and arrangement of information blocks (e.g. title blocks), notes, lists, revision information, view states, restriction notices, and the use of optional or supplemental blocks (see related term "Drawing Format").

c. Type 3D—3D TDP. Type 3D will include one or more of the following as specified in the contract and TDP Option Selection Worksheet:

(1) 3D native models.
(2) 2D drawings derived from the 3D native models.
(3) 3Di PDF viewable data derived from the 3D native models.
(4) Neutral files derived from the 3D native models (e.g. JT, STEP, etc.).

ISO 10303-242, Industrial automation systems and integration — Product data representation and exchange —Part 242: Application protocol: Managed model-based 3D engineering, is the merging of two ISO standards:

- Aerospace's STEP ISO 10303-203, Industrial automation systems and integration — Product data representation and exchange — Part 203: Application protocol: Configuration controlled 3D design of mechanical parts and assemblies, and
- Automotive's STEP ISO 10303-214, Industrial Automation Systems and Integration – Product Data Representation and Exchange – Part 214: Application Protocol: Core data for automotive mechanical design processes.

Digital data standardization should be specified when:

a. The potential for reuse of data exists; reuse may not be the same as for reviews or other occasions to "revisit" the data.

b. A need exists for interoperability of standardized data among NASA Centers and programs/projects with contractors, industry, partners, academia, services, and platforms.

c. The need to provide relationships between data for performing program/project management, systems engineering, and operational functions exists.

An acquisition framework creates the foundation and baseline from which all other collaborative MBE projects and programs should be driven. Interoperability and collaboration between NASA (and their Government Centers and JPL) and commercial program partners is a daily event, and the need for an updated process for dealing with digital data is required.

It is critical and incumbent for the program/project to review, redefine, and reuse current and applicable NPRs as well as handbooks and collateral, including, but not limited to, DRDs, PDLM, and systems engineering to accommodate model-based sharing and milestone delivery at KDPs in Pre-Phase A through Phase F.

The collaboration framework is being driven not only by NASA standards and needs but also by leveraging commercially defined leading and best practices. The goal is optimum model exchange definition with consideration for current to trending Government and industry needs.

Guiding principles for data collaboration include:

a. Data as an essential enabler should be made visible, accessible, and understandable to any potential user as early as possible in the program/project's life cycle to support project and mission objectives as constrained by security and access needs.

b. Data assets should be made visible by creating and associating metadata ("tagging"), including, but not limited to, discovery metadata, for each asset.

c. Developed metadata standards should comply with applicable national and international consensus standards for metadata interoperability; all metadata should be retrievable using the NASA Centers' systems with requirements to access the metadata.

d. Data assets should be accessible by making data available in shared spaces; all data assets should be accessible to all users at the NASA Center except where limited by law, policy, or security classification.

e. Data that is accessible to all users at the NASA Center should conform to that Center's specified data publication methods that are consistent with the Center's current and planned information systems capabilities.

f. To enable trust, data assets should have associated information assurance and security metadata and an identified authoritative contractor and/or Center-level source for the data.

g. Data interoperability should be enabled through business and mission processes reusing the Center's information system capabilities.

h. Semantic and structural agreements for data interoperability should be promoted through communities consisting of data users (producers and consumers) and system developers.

i. Data interoperability concepts and practices should be incorporated into education and awareness training and Center-level processes.

j. Programs/projects should acquire the minimum essential contractor-originated data required to meet all program/project life-cycle requirements.

k. Program/project managers and delegated Technical Authorities should consider data requirements for future procurement needs in a manner that fosters competitive procurement opportunities.

Three process domains require initial focus for MBE process interoperability:

a. Data collaboration (the definition and management of data, including models, requirements, CAD parts, CAD model libraries, and other mechanisms that contribute to a complete and valid design through design, development, test, and evaluation (DDT&E)).

b. Engineering release (the very beginning of design data CDM where engineering designs are created, checked, and status is reported).

c. Integrated product structure (the core mechanism around which the relationships between detail product design elements are defined).

Processes are to be implemented concurrently, authorized via institutional mechanisms such as NPRs and standards, and used as expected by trained and supported end users.

Process interoperability also involves inventorying existing mechanisms such as currently deployed capabilities and other application systems (e.g. approved parts list may be in another database), locally approved processes, and the expected practices articulated in project plans, contractor practices, or external standards called out in contract language.

Centers have their own documents and implementations inside systems of these processes, and there may be multiples of each. So, interoperability must be addressed to:

a. Elaborate on the definition of the process domain.

b. Eliminate or reduce risk as a main thrust of collaborative decision making.

c. Focus on systems of systems impact across all boundaries.

d. Collect data on the current state of things—who has what solutions in place now, in what form, how extensive, what problem does it attack, are they usable outside of any given Center, what is their effectiveness, etc.

e. Create operational concepts (abstract, user-centric interactions) that convey the desired outcome in a solution-independent way.

f. Generate multiple solutions and do trade studies on those solutions leading to recommendation(s), with rationale.

g. Identify the impact of recommendations.

D.4 Digital Collaboration Framework and Environment

Data today is generally electronic; and as the design environment continues to move toward a models-based approach, engineering/acquisition processes are more automated and demand a highly collaborative/social workforce during all phases of the life cycle for effective utilization and collaboration of MBE information (i.e. model-based “DATA”—Design and Definition, Systems Engineering, Simulation and Test).

Additionally, with the advent of digital definition and the ability to annotate these model-based artifacts, non-graphical definition can be represented in the model definition and can include:

a. DRDs for collaboration governance, contracts definition, and enforcement to properly define KDP deliverables per contracted levels and per interoperability definition and expectations.

b. Safety and Mission Assurance (SMA) problem reporting and corrective action, hardware screening, reliability, failure mode and effects analysis/critical items lists, etc.

c. Operations, when the system is on-orbit operational and mission operations needs access to the authoritative data.

d. Management oversight and awareness when management needs access to the dashboard to see if any trends were previously identified.

e. Software interoperability with the ability to insert new software modules and the Data Architecture allow for software upgrades while maintaining configuration.

f. Common data schema.

g. Standards-based-driven requirements.

h. Configuration and data management of the models to ensure data integrity and model validation.

i. Risk and risk mitigation.

The collaboration framework addresses the acquisition and storage of all program/project data, including the following:

a. Product/program definition.
b. Data collaboration framework (from acquisition through retirement).
c. Data definition (model-based design for "x," where "x" represents different artifacts).
d. Systems engineering.
e. Requirements management.
f. Mechatronics management.
g. CM.
h. Engineering revision and version control.
i. Risk management.
j. Other artifacts developed within the product life cycle**.**

The data definition principles require aligning the organizational governance model and the technology, taking into account the following scenarios and guiding principles:

a. Today's product data requires special handling due to its dependence on technologies such as system modeling (SysML™) and 3D CAD.

b. Product data is created and usable in different forms (lightweight and native) by different communities across the full product life cycle.

c. Minimizing the building of custom solutions and customizing out-of-the-box software and rely on external standards and configurability.

d. NASA standards for naming and CDM are followed to ensure proper DRD compliance, expected search and capture results, and effective communication.

e. Institutional knowledge is leveraged from MBE implementers across NASA and their ecosystem to provide a consistent approach to MBE.

D.5 Collaboration Definition and Environment

Collaboration should consist of a virtual development environment that allows immediate, secured access to all product data via light-weight visualization tools. Without effective collaboration, team members who are not co-located are forced to share documents using e-mail, zip files, and/or a shared server; use multiple tools for collaboration that could manipulate the native format or that could transfer insufficient product information; and always search for the latest version of record.

The MBE collaboration environment creates a development environment that represents all types of "digital" data, including, but not limited to, specifications, requirements, analysis results, and legal entities, and instills a flexible discipline-enabling access to the right information at the right time to the right people. The MBE collaboration environment, when leveraged and deployed correctly, can have a major impact on mitigating risk, reducing cycle time, improving quality, and ultimately, cost savings. It also allows for a quick and robust way to make decisions while not incurring any cost on physical prototypes or models. In the end, it is a means toward reducing risk by aiding the decision-making process.

Organizations embracing an MBE collaboration environment vision define the following four themes as what makes or breaks a successful execution:

a. **Integrity of the data**—having the latest and most correct data from the onset (whether internal or within the contracts that define the exchange of information). The data have to be complete as well as consistent, making sure that the right information is available. DRDs will define the level of depth and detail needed, as well as how that information can be exchanged to ensure integrity is enforced.

b. **Virtual access anytime/anywhere**—global sharing, including security and safeguarding of data, as well as supply chain enablement, is critical to handling complex systems from both a push and pull perspective as part of operational workflow. This capability is critical for operations such as engineering release or change management, making sure the data is available at the right time to the right people. The completeness and integrity of the data and ability to access information 24 hours, 7 days a week are expected.

c. **Discipline in integrated product definition-driven development**—stemming from the integrated product structure, including options and variants. Once the structure is defined, management of configurations and changes needs to be scalable as well as enforced.

d. **Visualization**—just beginning to be referred to as "virtualization"—using light-weight and intelligent visualization software that is capable of total product representation and animation for form and fit decisions, analysis, management, and assembly.

Successful product development for NASA relies on some key capabilities as follows:

a. Visibility and management of requirements throughout the product development process.

b. Access to a more complete "data model" at any time during the development process that represents an intelligent and fully defined artifact versus an amassing of multiple documents from remote resources.

c. More informed decision making for the appropriate selection of design strategy.

d. Ability to better leverage and enable the different program/project levels and primes by bringing them closer to the product development life-cycle phase and decision process.

e. Ability to reuse products and processes and incorporate new requirements as needed/when needed.

f. Flexibility for domain autonomy built into product design and manufacturing processes.

g. Validation of functional product and process capability to ensure that products meet the needs of the Agency and that processes work effectively.

While MBE can provide value and help achieve some of these technical goals, it will not be totally successful without changes in many domains. Development of an MBE collaboration environment is essential in fully achieving these goals. As a part of executing an MBE collaboration environment strategy, desired data end states have to be converted into more specific objectives as follows:

a. Pre-release Data Sharing—

(1) When serving as systems integrator, engineering data have to be shared with other engineering groups, including to and from primes, prior to formal engineering release.
(2) Vertical data movement (e.g. downward for requirements, upward for analysis results) supports decision making but does not support the horizontal and diagonal flow of data, especially CAD and other specialized data. The question was how to keep track of which version of the model was used and for what.
(3) Today, if a problem is found in that model, the capabilities to share such data may outstrip the organizational capacity to facilitate and monitor it. MBSE, along with M&S, does a very good job of defining the infrastructure that defines access and what is required to answer many of these questions; but it is the MBE collaboration environment framework (as defined by the other initiatives) that makes the access and sharing possible.

b. Distributed, Non-Document-Centric Authority—

(1) Product structures and designs are just some of the data managed in systems. They cannot serve their purpose if the electronic version is not authoritative.

(2) On many projects, authority for design is distributed unequally: the number of data objects to be reviewed and approved increases non-linearly as one goes DOWN the product hierarchy.
(3) Furthermore, the distributed vehicle elements are simultaneously in different design states; highly distributed authority combined with the interlinked data structures of CAD complicates the dynamics of intra-element flow of design data.

c. Process, Tool, and Use Synchronization—

(1) In an MBE collaboration environment, the processes and workflows are implemented in the tool suite and provide real value when they are actually used.
(2) The engineering release definition, as well as NPR 7123.1, defines this model; and MBE can act as the framework to ensure that the right data is available at the right time.

d. Handling Data Objects—

(1) The larger picture of significant design data being created by primes and partners really shines a spotlight on scalability and usability challenges experienced today around handling objects within MBE environments. Definition of the need for the model and its attributes is blurred; therefore, native data (which can be very large in itself) carries a lot of unnecessary baggage that will never be used by the recipient.
(2) New ways of thinking are needed about what it means to make a "delivery," to "receive" and/or "use" a model (or representation), which then needs to be properly reflected in the DRD clause, to "release" a design, and how to deal with ownership, change, and configuration control around complex data entities that are still actively being defined and do not behave like PDF files or drawings.

e. Having a Voice—

(1) NASA has dynamic needs because the mission is research, science, and exploration. The mission is to do things that have not been done before.
(2) When processes are linked to tools and one cannot do the job without the data that is in them, a move toward processes enabled by technology is necessary:
    A. Who gets to decide on the requirements for the application?
    B. Who gets to influence the decision on the trade analysis results?
    C. Who gets to move their problem to the top of the "to do" list?
(3) Governance has to recognize the needs of different users to be heard at different times, and the infrastructure has to support it.

f. Data Usability and Collaboration—

(1) Capability deployment that maps to defined user communities. Achieving this landscape will require both technical and process solutions to be designed, built, configured, tested, deployed, used, and supported.
(2) Additional attention to enable the move from document centricity to data will require focus on new practices, including contract language (DRD clauses) and supporting tools, around specification of technical data packages, and the conduct of CDM.

D.6 Collaboration Planning and Development

MBE is a critical element with technical and programmatic implications. Management at the Agency, Mission Directorates, programs/projects and their delegated Technical Authority(s) have the responsibility to determine the following at their respective levels:

a. How much should be risked (or how much should the program/project pay) to ensure the relevant data exist and are accessible, discoverable, and understandable to support such events as some in-flight anomaly 10 or more years in the future?

b. Where should the Agency and the program/project invest their limited attention and resources on data during the development cycle?

The MBE Plan (refer to Appendix J for guidance in developing the Plan) documents the foundation for these decisions. The program/project managers and the delegated Technical Authority(s) sign and release the Plan prior to the completion of the System Definition Review (SDR). A program/project's compliance with NPR 7120.5 is verified by submission of the initial preliminary Plan. A program/project manager and the delegated Technical Authority(s) require support in the development of the strategy and the Plan.

The Program Manager and delegated Technical Authority(s) are responsible for documenting in the MBE Plan the scope of each Center's responsibilities and partner/prime or supplier requirements for collaboration, including:

a. The implementation approaches.

b. The environment in which the program and its projects' MBE solution(s) operates.

c. The level of digital maturity required for decision enablement and effective passing of digital information.

d. The timing for implementation of the MBE solution and associated processes, data, elements, attributes, and formats.

e. Proof of compliance.

The MBE solution architect, program/project manager, and the delegated Technical Authority(s) are supporting roles that may assist in the development of a program/project management team by providing technical program/project strategy and oversight leadership support and advising the program/project manager and the delegated Technical Authority(s) on how to facilitate knowledge transfer, education, technical direction, and consultation from program/project beginning to end of life as follows:

a. **Long term**—Focusing on the end-to-end enterprise-level system/solution design and roll-out strategies that drive toward implementation delivery (associated with) and sustainment of the following:

(1) Identification and development of the technology roadmap based on desired end state.
(2) Process alignment and optimization by proper application of enabling technologies.
(3) Design consultation, including security, authentication, authorization, and integration.
(4) Product capability deployment, features, and functionality.
(5) Automation processes and methodologies.
(6) Knowledge management, best practices, and reuse strategies.
(7) Performance of the role of the senior technical designer on the project.
(8) Drive the linkage/enablement of the designed architecture to domain processes such as CDM, engineering release, change management, etc.
(9) Lead the development of the system and application architecture definition and application configuration, including:
  A. Hardware and software components of the system.
  B. Interfaces and interoperability.
  C. Infrastructure and security.
  D. Performance and reliability.
  E. Administration and access control.
  F. Maintenance and sustainment over time.

b. **Near Term—**Focusing on architecture implementation of next delivery milestones by the following:

(1) Lead and drive the development and review of all related infrastructure, architecture, and design components.
(2) Lead the development of the system description and architecture design.
(3) Lead the development of any customization designs.

(4) Lead the technical review of the use-case scenarios, requirements, and deployment decisions.
(5) Chair and conduct design, code, and configuration reviews allowing project management to enforce consistency with the overall technical architecture.

In addition, the following personnel have the responsibility to participate on the program/project management team in the stated capacities:

a. **Tool Implementation Lead**:

(1) Conducts the installation of the tool (software, etc.) and third-party applications.
(2) Configures and sustains the tools/applications following installation of the tool by the Agency CIO, or designee, including:
A. Access control.
B. Data/folder structures.
C. Workflow design and configuration.
D. System test and validation.
E. Data migration.
F. Data retrieval from external systems.
G. Development of test scripts.

b. **Process Lead:**

(1) Leads the definition of overall business requirements (key process areas and indicators).
(2) Leads the gathering and analysis of solution and system capability/functionality.
(3) Leads the assessment of as-is business process documentation and gap identification of process documentation.
(4) Leads the definition and documentation of business use cases via concepts of operations.
(5) Interfaces with the solution architects regarding system capability to ensure defined processes are achievable within the technology and within program/project milestone constraints.
(6) Analyzes complex customer business process requirements to evaluate alternatives and identify options within the solution system architecture.
(7) Ensures the development of process definition and use-case documentation.

APPENDIX E

ARCHITECTURE

E.1 PURPOSE

Collaborating within and outside NASA will be greatly enhanced through digital and model-based methods. This Appendix provides guidance for a consistent architectural framework, which is necessary to ensure compatibility.

E.2 MODEL-DRIVEN ARCHITECTURE

The OMG initiative defines model-driven architecture (MDA), which is leveraged by several standards such as Meta-Object Facility, XMI, common warehouse metamodel (CWM), Common Object Request Broker Architecture (CORBA), and Unified Modeling Language (UML). The former approach relied on Executable UML and Object Constraint Language (OCL) instead, and query/view/transformation (QVT).

MBA's "eco-system" of programming and modelling tools are represented in general terms by the Eclipse Modeling Framework. This framework allows the creation of tools implementing the MDA standards of the OMG; but, it is also possible to use it to implement other modeling-related tools.

NASA believes that existing standards do not provide sufficient resolution to create collaborative models; therefore, the establishment of an Agency-level collaborative environment and architecture is critical for program success. Other NASA Technical Handbooks will be developed to reflect more information toward recognizing and implementing the appropriate architecture.

Discussion goes deeper and reviews the implementation of MBE requirements for the establishment of Agency-level collaborative environment types. Implementation of MBE requires the establishment of an Agency-level collaborative environment and architecture defined as four types of architectures:

a. Security.
b. Information Support System.
c. Data.
d. Process.

E.3 Architecture Rationale

Collaborating within and outside of NASA will be greatly enhanced through digital and model-based methods. A consistent architectural framework is necessary to ensure compatibility. Existing standards do not provide sufficient resolution to create collaborative models.

In accordance with the life cycle in NPR 7120.5 (with tailoring for projects less rigorous than a flight project), the life cycle for this activity follows:

a. Pre-Phase A: Define the mission and study multiple approaches to the framework.

b. Phase A: Define top-level architectural framework requirements and select a single approach.

c. Phase B: Complete architectural framework requirements and perform preliminary design of architectural framework.

d. Phase C/D: Complete and build the framework.

Goddard Space Mission Architecture Framework (GSMAF) follows ISO/IEC/IEEE 42010 and other community standards such as NPR 7120.5 and NPR 7123.1. GSMAF is structured to address needs and concerns of primary stakeholders for Goddard Space Flight Center science missions:

- **Science Viewpoint** – What do the Principal Investigator and Science Team care about?
- **Systems Engineering Viewpoints** – How do we design, build, and test "The System?**"**
  - Requirements – What are the necessary and sufficient aspects of the product(s) that will execute the Mission?
  - Product Design – What are the definition/designs of the product(s) elements necessary to execute the Mission?
  - Realization Viewpoint – How do I build, integrate, and test the product elements?
- **Management –** How do we manage a team and resources to design, deliver, and operate the product(s) to execute the Mission?
  - Project Development Viewpoint – What are the project schedule, budget, risk, resources, and organization required to define and deliver the product(s)?
  - Operations Viewpoint – What are the plans, rules, and procedures for "Mission Operations?"
- **Enterprise Viewpoint** – How does the effort currently align with programmatic and institutional policy, direction, reporting, and resources?

E.3.1 Security Architecture

The Security Architecture exists to ensure continuity of Mission Directorate operations for both flight projects and ground operations through the management of risks and vulnerabilities to protect humans, flight and ground facilities, information, systems, and services against disasters, threats, errors, and manipulation.

The Security Architecture is a collection of components or layers of security that provide information assurance. These include policy and security management, application security, data security, platform security, network and perimeter security, physical security, and user identity security. It provides the program/project with reliability, quality, integrity, availability, and confidentiality of data and systems in compliance with Federal and Agency regulations and requirements.

It is the responsibility of the Agency CIO to develop the Security Architecture as defined in NPR 2800.1, Managing Information Technology, and NPR 2810.1.

The program/project managers and the NASA Chief Engineer, or delegated Technical Authority(s), have the responsibility to ensure that appropriate IT elements and approved IT security plans are in place and address the elements as required by their Center-level procedural requirements documents.

E.3.2 Information Support System Architecture (ISSA)

The ISSA is comprised of IT components allowing users to access all model-based definition data under a configuration-managed, secure environment. The ISSA allows programs/projects to capture, integrate, and manage product and process information from diverse authoring applications in a single environment.

This MBE environment enables the definition and standardization of workflow-driven processes that can be leveraged and used across multiple programs/projects. The ISSA is designed to integrate multiple mission-critical systems through the use of industry standards in MBE (e.g. open application programming interfaces [APIs] and enterprise service buses) to aggregate and extend knowledge sharing throughout the organization. It is the responsibility of the Agency CIO to develop the ISSA.

The Agency CIO has the responsibility to ensure that IT and information resources are acquired and managed in a manner that implements the requirements, procedures, and priorities defined by NPR 2800.1 and ensure that IT products, services, and information systems meet customer and stakeholder requirements.

E.3.3 Data Architecture

A Data Architecture describes how data are processed, stored, and utilized in a given system or product definition. It provides criteria for data processing operations that make it possible to design data flows and also control the flow and association of data in the system. If programs/projects do not have the Data Architecture from the start, the program/project data becomes disorganized quickly and is nearly impossible to electronically integrate or discover as the level of data increases over time.

The Data Architecture provides for creation, storage, and exchange of data, especially PDD, models and simulations, and for the requirements imposed on the MBE solution elements to support data interoperability, management, integration, metadata, and work practices, including, but not limited to, standardized taxonomies and ontologies, and should be based on common, open standards or NASA standards.

The Data Architecture processes and requirements have to be flexible to accommodate changes in MBE vendors, NASA Center and institutional software, and environments and allow the inclusion of external suppliers or partners that use their own local MBE environment or do not currently support an MBE environment.

The CIO provides the infrastructure/systems for implementing an architecture that supports the creation, storage, interoperability, and exchange of data. Engineering defines the program/project data that the architecture has to support and the criteria for data processing operations, data flows, and the association of data in the system. Further, engineering supplies the requirements for the infrastructure/systems needed to meet these criteria. The program/project manager and delegated Technical Authority(s) are responsible for ensuring that the Data Architecture meets the program/project's needs. The program/project Data Architecture should be defined and documented in the MBE Plan.

E.3.4 Process Architecture

Processes enable the integration of diverse human and systems activities to coordinate the exchange of services and data/information, including process design, process execution, and process monitoring. A Process Architecture is a description of the program/project business processes. The Process Architecture establishes standards in how the program/project will create, manage, and control program/project data. A Process Architecture describes data interoperability requirements at defined life-cycle states and maturity levels (both internally and externally to NASA); describes which processes will be applied across all projects (e.g. safety and mission assurance, deviations and waivers, corrective actions, and problem resolution); and identifies the source for documented common nomenclatures and schemes for product naming, numbering, and version control.

The MBE Process Architecture defines flow of the program/project data, the roles and responsibilities for data handling, and the approval authority. The Process Architecture should clearly define, control, and integrate business and engineering processes for program/project execution based on results from life-cycle cost analyses. Processes should be subjected to value-added analysis techniques (e.g. streamlined, efficient, effective processes) prior to implementation. A well-defined Process Architecture will ensure that every person or organization involved executes the process. Each process to be used is fully documented so that everyone understands their respective involvement in the process.

The program/project manager and delegated Technical Authority(s) are responsible for defining the relationship between businesses and engineering processes and documenting these relationships in the MBE Plan. The Agency CIO and applicable Mission Directorate are responsible for implementing the requirements of the Process Architecture

If established early and properly, the key benefit of the MBE Process Architecture is that all program/project team members will clearly understand data control and release, including which data are authoritative and the process through which the data are released to become authoritative.

APPENDIX F

INTEROPERABILITY STANDARDS

F.1 PURPOSE

This Appendix provides guidance for establishing the proper data interoperability capability. In recognition of adopting a true collaborative MBE environment, NASA needs to adopt industry standards and approaches for digital data interoperability, which will enable data interoperability and move beyond the storage of raw, uncorrelated data.

The true benefit of a model-based environment may not be seen at the Center or authoring level; however, upstream and downstream users are hugely impacted as the amount of work required to validate or modify the completeness or correctness of the data being shared increases. NASA-STD-7009, Standard for Models and Simulations, provides requirements for determining the credibility and integrity of model-based results and model application.

Furthermore, a model-based environment as part of an MBE strategy also covers the integrity (security, relationships, revision currency, effectivities, interoperability, standards compliance, etc.) of the data.

F.2 INTEROPERABILITY

Table 5, System and CAD Model Interoperability Insights for Project Data Acquisition and Exchange, illustrates use of data in a models-based environment, in particular for 3D CAD interoperability, and how to facilitate better planning and acquisition of design data.

Table 5—System and CAD Model Interoperability Insights for Project Data Acquisition and Exchange

If we want to:	we would need model-based definition (annotations and properties):
Perform design and design intent integrations	Pre-release models (systems and CAD) with data appropriate for the life-cycle phase to defined (high) accuracy based on negotiated agreement between provider and user.
Subcontract part of design work	To send contractor requirements, skeleton files, start parts, approved parts lists, BOMs, etc., and receive back from them design files, component models, and other elements of the product definition package.

If we want to:	**we would need model-based definition (annotations and properties):**
Take over design change authority	Full design history, systems, and CAD models for a given vehicle block, including skeletons, standard parts, start parts, drawings, configuration settings, and model-checking criteria.
Conduct design review	3D “viewable” of released models or external alternative representations that support annotations and analysis.
Do derivative designs such as Ground Support Equipment	Pre-release CAD and system models from source at defined maturity level treated as “released” by users within their own environment with associated metadata appropriate for the life-cycle phase.
Do modeling and simulations	Pre-release alternative (system and analytical models) representations with full definition of items significant for modeling and simulation with data appropriate for the life-cycle phase.
Re-bid production	Released CAD models, drawings, material specifications, manufacturing processes, installation models, etc.
Do physical integration and verification (e.g. at Product Assembly Building)	Released alternative representations or source system definitions, requirements, and CAD with appropriate alternative representation substitutions with full definition of items at integration point (but lacking internal detail) with data appropriate for the life-cycle phase.
Define contents of Acceptance Data Package	CAD needs based on defining requirements—who/what/when/how models will be used—to ensure that they are the right life-cycle/maturity state, format, and contain needed content.
Perform Concept Development and Refinement	Surface, shape, parametric, possibly detail design or as-is (for existing systems) and “will-be” (for future systems) model and simulation data.

F.3 Exchanging and Distributing Models

To ensure data transportability and integrity, the need for NASA to adopt industry standards and approaches for digital data interoperability is required to enable data interoperability and move beyond the storage of raw, uncorrelated data.

Proper data interoperability capability is only achieved through the identification of IT standards and the application of contractual methods to ensure implementation and alleviate the data interoperability limitations that currently challenge NASA's programs/projects.

Multiple options for data interoperability among NASA Centers and programs/projects with contractors, industry, partners, academia, services, and platforms exist. For example:

- CAD systems are all moving toward 3D digital formats as their means of the authoritative source and definition. Exchanging 3D data within engineering departments, between primes, and with other divisions and departments is critical to program/project development; however, not all of these use the same CAD system.
- When parts are developed in 3D, the data is initially stored in the original format in the authoring system (or PLM) of the software used to design the part; but, when the need to share/collaborate occurs, a neutral 3D format is necessary. (Refer to NIMA-RPT-004). In general, a neutral 3D format as the medium for collaboration should be selected.

Note: The program/project manager and delegated Technical Authority(s) have the responsibility to identify and acquire essential contractor-originated data with sufficient access and usage rights to support not only the full program/project life cycle, but also the enterprise needs of the Mission Directorate and Agency as a whole. Contractor data interoperability is achieved through identification of IT standards and guidance on contract language.

F.4 Standards

Table 4 illustrates use of data in a models-based environment, in particular for 3D CAD interoperability and how to facilitate better planning and acquisition of design data.

F.5 Model-Based Engineering Standards Elements

The well-defined MBE environment should:

a. Host the library used for authoritative (x) CAD designs.

b. Provide a distinguished security and access model for the libraries that restricts all changes to a designated set of librarians.

c. Provide efficient mechanisms for managing large families of similar items.

d. Prevent or reduce the occurrence of duplicate or multiple part numbers and designations for an identical physical device; a part number should map to a specific, unique set of specifications.

e. Address the maintenance of additional metadata for standard parts such as standard identifiers, extensions for tracking the configuration of mission sets, and effectivities which map revisions/versions to the extensions.

f. Manage the parts data developed by the design organizations developing the product.

g. Allow for inclusion of new libraries and mechanisms as new organizations enter the environment, new suppliers are added, and parts suppliers are consolidated or removed from the marketplace.

h. Provide for library availability for the required life cycle of the program/project.

i. Host the library used for requirements development and requirement-to-part associations.

F.6 Industry Standards for Data Interoperability

Table 6, Target Industry Standards for Data Interoperability Formats, provides guidance for industry standard data interoperability formats that are well suited for relational and object model data interoperability implementations at the time of this document's release. For reference documents, see Appendix K.

The interoperability formats in Table 6 are based on the World Wide Web Consortium (W3C)[11] Internet Standard: XML and supporting protocols. These standards are specific to the applicable data interoperability formats in maturity level 3 in Table 8.

Table 6—Target Industry Standards for Data Interoperability Formats

Standard	Short Description	Industry Organization
[1] Extensible Markup Language (XML), version 1.1	Extensible rules for encoding documents	W3C
[2] Namespaces in XML, version 1.1	Rules for uniquely naming elements and attributes	W3C
[3]XML Schema Definition (XSD)[12], version 1.1	Defines the structure, content, and semantics of XML documents	W3C
[4]XML Metadata Interchange (XMI), versions 2.1.1 and 2.1	Standard for exchanging metadata information via XML	OMG
The STEP Application Protocols (AP) ISO 10303	Standard for the Exchange of Product (STEP) model data for systems engineering	ISO

[11] World Wide Web Consortium, http://www.w3.org/
[12]XSD is a schema whose purpose is to document the elements of the XML document, their meaning, and their structure.

Note Standard Definitions:

1. [1]XML: XML is a simple, very flexible text format derived from Standard Generalized Markup Language (SGML), ISO 8879, Information processing – Text and office systems – Standard Generalized Markup Language (SGML). Originally designed to meet the challenges of large-scale electronic publishing, XML is also playing an increasingly important role in the interoperability of a wide variety of data on the Web and elsewhere.

2. [2] Namespaces in XML: XML Namespaces[13] are a simple and straightforward way to distinguish names used in XML documents. XML Namespaces provide a simple method for qualifying element and attribute names by associating them with namespaces identified by Uniform Resource Identifier (URI)[14] references.

3. [3]XML Schema: XML Schemas (per XSD) express shared vocabularies and allow machines to carry out rules made by people. They provide a means for defining the structure, content, and semantics of XML documents in more detail.

4. [4]OMG XML Metadata Interchange (XMI): The main purpose of XMI (ISO/IEC 19503, Information technology – XML Metadata Interchange (XMI), is to enable easy interoperability of metadata between application development life-cycle tools such as modeling tools based on UML (ISO/IEC 19501, Information technology – Open Distributed Processing – Unified Modeling Language [UML]), and metadata repositories/frameworks based on the Meta Object Facility [MOF]) (ISO/IEC 19502, Information technology – Meta Object Facility [MOF]), in distributed heterogeneous environments. XMI integrates the following three key industry standards:

    a. XML.
    b. UML, an OMG modeling specification (ISO/IEC 19501). (Note: XMI is expressed as UML and is listed here for completeness.)
    c. MOF (ISO/IEC 19502).

5. STEP Application Protocols (APs): "Standard for the Exchange of Product (STEP) model data for systems engineering" or ISO 10303 "Industrial automation systems and integration — Product data representation and exchange," contains various APs. The STEP APs (e.g. ISO 10303, Part 209; Part 210, Industrial automation systems and integration - Product data representation and exchange - Application protocol: Electronic assembly, interconnect and packaging design; Part 233; Part 238; Part 239; or Part 242) capture data on components and systems to improve computer-sensible

[13] Namespace in XML1.1, http://www.w3.org/TR/xml-names11/
[14] Uniform Resource Identifier, RFC 3986/STD 66 (2005), http://tools.ietf.org/html/rfc3986

sharing of important product information by supporting the capture, interoperability, and archive systems engineering information across disciplines and organizations. See STEP AP descriptions in K.2, References.

F.7 Interoperability and Sustainability

Program/project managers and delegated Technical Authorities are responsible for determining the MBE interoperability and sustainability requirements and ensuring these are identified across all participating organizations and in all program/project contracts. Inclusion of international partners could have a different set of interoperability and sustainability requirements that would need to be addressed. The following provides guidance to assist with the development of these requirements.

Common problems related to interoperability are listed in Table 7, Common Problems Related to Interoperability.

Table 7—Common Problems Related to Interoperability

Issue	Activity/Problem Examples
Requirements Interoperability	• Determine whether requirements are ready for use by another department or engineer in a work group. • Determine level of requirements and specification usage. • Rework due to incompatible requirements settings.
Modeling and Simulation Results	• Identify the models affected by a change or updates as a result of modeling and simulation results. • Determine whether design data exist and are in a status to be used for decision enablement or procurement. • Identify all interfaces and navigate to the interface definition document/design object. • Link system design, analysis, and validation.
CAD Interoperability	• Determine whether CAD (ECAD and MCAD) files are ready for use by another engineer in a work group. • Determine level of CAD file usage. • Rework due to incompatible CAD settings.
Product Definition	• Identify the software affected by a change in hardware. • Determine whether design data exist and are in a status to be used for procurement*. • Identify all interfaces and navigate to the interface definition document/design object*. • Link part design (e.g. CAD) to one or more specific requirement records**.

Issue	Activity/Problem Examples
Part Identification and Naming	• Avoid CAD file name conflicts when combining CAD data from multiple sources. • Compare the definition of two product configurations to be used for analysis. • Reduce error and confusion over nomenclature.
Model Definition	• Identify when an alternative representation of a CAD file needs to be updated (e.g. a detail part on a subassembly changes and when other CAD models get updated). • Identify all interfaces and navigate to the interface definition document/design object*.
Common Hardware Handling	• Find and replace all instances of a specific part that are in a certain life-cycle state*. • Identify common hardware parts even when provided by different design sources. • Identify parts requiring human flight-rated qualification*.
Product Life Cycle	• Confirm the delivery status of product data associated with a contract design deliverable. • Determine whether design data exist and are in a status to be used for procurement*. • Find and replace all instances of a specific part that are in a certain life-cycle state*. • Trace the status changes of a part in life cycle (e.g. changes during "as-manufactured" state)*. • Provide visibility of active engineering changes; show impact on next-higher design objects*. • Identify product objects not in life-cycle state needed to support their higher-level assembly.
Product Structure(s)	• Create and approve a product structure(s) from both contractor and NASA sources. • Add the product structure(s) and design data from a subcontractor into an existing product structure(s) and control access based on approval/acceptance status. • Update a branch in a product structure(s) (add, delete, revise) based on the product structure(s) received from a contractor. • Identify parts requiring human flight-rated qualification*. • Assess the impact of a part being made obsolete (or otherwise being unavailable). • Identify the detailed configuration of a major test. • Trace the status changes of a part within a given life-cycle state*.

* Relies on more than one standard.

** Standard needed to support IT application integration.

APPENDIX G

USE CASES FOR ESTABLISHING MBE ELEMENTS AND INTEROPERABILITY REQUIREMENTS

G.1 PURPOSE

This Appendix provides four use cases to consider when establishing MBE elements and interoperability requirements in correlation with Table 6. Understanding neutral format data usage allows for the appropriate tools to be selected in the most cost-efficient manner, efficient data exchange mechanisms to be established, and for everyone requiring data access to have that access at the required level.

G.2 USE CASES

The use cases are defined as follows:

a. Viewing:

(1) If the use of a CAD system is not desired, the visualization of engineering data using 3D viewers comes into play in a number of different situations: the presentation of product data, the representation of 3D models for information purposes (e.g. for a design review or marketing), and the realistic representation in virtual reality systems.
(2) While the simple viewing of the geometry is sufficient in many cases, in other cases, metadata or PMI also needs to be displayed.
(3) The high-performance visualization of large assemblies or design spaces and neighboring geometries is often an important criterion.
(4) In cases such as these, it is especially important that simplified representations are used.
(5) The most important needs for simplified representations are:

A. The source system-independent representation of the model data (geometry and metadata) with the required level of detail.
B. The ability to filter the product structure (e.g. using views or layers).
C. The execution of simple measurements.
D. Representation of PMI.
E. The ability to represent textures and sources of light for applications in the area of virtual reality.
F. The availability of easy-to-use, cross-system viewers.

b. **Data Exchange**:

(1) In development processes, it may be necessary to exchange exact geometry between different authoring systems such as requirements or CAD systems. This is, for example, the case if a supplier is using a different CAD system than the one used by the manufacturer.

(2) Another common situation is that one of the development partners makes a change to the geometry after it has been exchanged. In this case, merely viewing the data is not enough. What is needed is a typical and frequently used modeling method involving design in context of existing geometry defined as follows:

A. When exchanging exact geometry, additional information describing the product is often needed. In this context, a distinction is made between PMI and metadata. While metadata refers to descriptions that consist only of text (e.g. information about the author or the release status of a model), PMI is often added in the form of 3D annotations, manufacturing notes, and material specifications.

B. This makes a greater demand on the underlying data format and on the application doing the processing. Grouping and filter options are needed to ensure clarity.

C. Another frequent requirement is that the processing of PMI be possible subsequent to data exchange. The protection of intellectual property is also playing an increasingly important role in data exchange, and it should therefore be possible to take this aspect into consideration and reflected properly in the DRD.

(3) The most important items to be considered are:

A. The data format and collaborative model definitions to ensure the transfer of exact geometry and the entire product structure.

B. The transfer of metadata, as well as PMI annotations (depending on the technical readiness level (TRL) being executed and where a concrete use case is involved).

C. Ensuring data integrity, fidelity, and completeness, and one-to-one correlation between the original model and the target model.

c. Data Integrity:

(1) Programs/projects are formulated and implemented following various NASA directives through multi-disciplinary teams of engineers and other personnel, with systems engineers, program/project managers, and delegated Technical Authorities working across the other engineering disciplines to achieve integrated

systems on schedule and within budget throughout the program/project life cycle. (Refer to NIMA-RTP-002, Data Integrity in NASA Programs and Projects[15].)

(2) A primary use of this data is for making informed decisions by individuals and teams, including decisions made at life-cycle reviews involving the evaluation of various aspects of the program/project. In each of the life-cycle phases and reviews, these multi-disciplinary teams work with a multitude of data related to the systems being developed, including requirements, verification requirements, test verification requirements, failure modes and effects, risks, hazards, and problem reports, among others, and are often linked to each other. In operations, the data becomes critical for determining the readiness of the systems, with the consequence of poor data integrity having potentially catastrophic effects, including loss of mission.

(3) Two major forms of data integrity have been identified as follows:

A. Integrity of Data Relative to its Authoritative Source

i. Integrity of data relative to its authoritative source is defined by the field of information security as the property that data have not been changed, destroyed, or lost in an unauthorized or accidental manner. In the context of NASA programs/projects, the most common and actionable form of this is the integrity of data relative to its authoritative source across and within a program/project.

ii. Within programs/projects, authoritative sources exist for various types of data involving, in many cases, the use of various discipline-specific tools and varying instances of the same tool. To conduct integrated analyses and reviews using data from one or more disciplines or from one or more tools, data from authoritative sources need to be integrated. The common, current practice is to manually copy data from its authoritative source into other tools, documents, or presentations. From the moment the data is copied out of its authoritative source, a risk that the data is out of date exists, as changes to data in the authoritative source are not automatically made in the manual copy; the integrity of the data from the perspective of the authoritative source may be compromised. Existence of data discrepancies presents a high probability program/project risk of incorrect decisions being made, inadequate integrity of the program/project integrated design being represented, or inadequate readiness of programs/projects and their associated systems being presented.

[15] The referenced white paper NIMA-RTP-002, Data Integrity in NASA Programs and Projects, traces requirements for data integrity to NASA Procedural Requirements and describes how data integrity is a critical factor for achieving integrity of the program's integrated design, as well as the readiness of the operational flight and ground data systems. It also provides data management lessons learned.

B. Integrity of Data Relative to an Authoritative Model

i. Integrity of data relative to an authoritative model is defined by the field of database systems as the property that data are an accurate reflection of the domain of discourse it is attempting to model. In the context of NASA programs/projects, the most common and actionable form of this is the composite and component integrity of data relative to an authoritative model.

ii. Authoritative models of valid forms of data exist, from a single piece of data relative to the model of a valid data type, range of data, or simple text rules (component data integrity), to more complex data involving multiple pieces of data relative to each other and an authoritative model (composite data integrity).

iii. The primary solution for improved data integrity is the use of information systems to change from manual processes of data integration and validation to automated processes.

(4) Two main approaches, automated data integration and automated data audits, are addressed as follows:

A. Automated Data Integration Relative to Authoritative Sources of Data

i. Goals of using this approach include improved data integrity and data accessibility and elevated efficiencies in data management over the full program/project life cycle.

ii. Lack of data integration has been identified as leading to cost and risk increases due to use of non-authoritative/out-of-date data, miscommunication of data, and missing data. With this approach, use of non-authoritative copies of data is minimized through automated data aggregation. Consequently, rates of engineering data discrepancies are also reduced whenever automated data aggregation is used. User communities can manage specific data in tools explicitly designed for the management of that data and can also implement specific processes that integrate data directly from the authoritative sources into reports and other formats.

B. Automated Data Audits

i. Performing automated audits using information systems is a proven approach that has high utility and relatively low cost.

ii. In the engineering realm, data audits can be performed daily or weekly to help drive convergence in design, and can serve to ensure the integrity of the data that is used in baseline versions of a multitude of engineering artifacts. This can be done at the elemental level with a single piece of data, or at the composite level with multiple pieces of data.

d. Data Interoperability Formats:

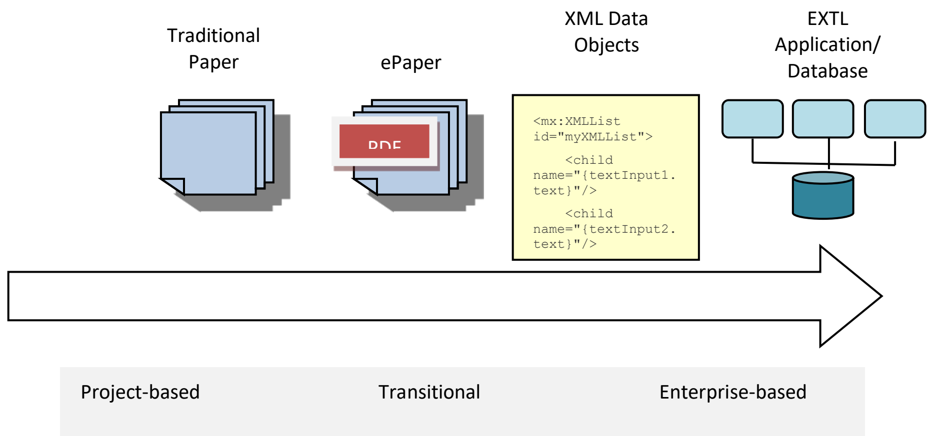
(1) Data interoperability refers not only to CAD data but also to non-CAD data used in innovation and preliminary designs and other pre-CAD domains (e.g. requirements analysis). All formats need attention and are considered part of digitalization. All data interoperability should follow standards where applicable (e.g. STEP, XML):

A. Requirements interoperability should focus on STEP AP 242, 239, 233 in ISO 10303 and also follow Regulated Qualifications Framework (RQF) or Requirements Interchange Format (RIF) standards.

B. CAD data interoperability formats should be chosen based on the need for interoperability or reuse after delivery.

(2) Currently, MCAD data formats may be selected from Table 6. In Table 8, Format Maturity Levels, a maturity level is assigned to each data format by which the dynamics of each can be judged against intended utilization. (Refer to NIMA-RPT-004.) However, users should assess the current trend in technology from other sources prior to selecting data interoperability formats.

Table 8—Format Maturity Levels



Maturity Level	Level 1	Level 2	Level 3	Level 4
Data Format Descriptor	Paper-based	ePaper	XML Data Object	Database w/EXTL
Delivery Mechanism	Physical Delivery	ZIP Electronic Delivery	ZIP Electronic Delivery	EXTL Application and Database Delivery
Standards Used	None	PDF	XML, XML Namespaces, XSD	The STEP Application Protocols (APs) (e.g., ISO 10303, AP203, AP209, AP214, AP233, or AP239)
Content Repository	File Cabinets	File Share to ECM	ECM to Structured Database	Structured Database
Recommended Utilization	Limited-life paperwork directly associated or co-located with hardware	Plans, papers, or other data delivered in association with hardware delivery/program management	Data intended to interact or affect other data within an enterprise environment	Data intended to interact or affect other data within an enterprise environment

Note: Intended Utilization Options

(3) To build off the format and maturity levels of available technologies, the following guidelines are provided for when to apply the format:

A. Level 1 (Paper): Documents delivered on the printed page.

Specify when reuse and/or life-cycle maintenance of materials is not desired. *Note: This approach is not recommended nor supported under MBE.*

B. Level 2 (Formatted Documents)[16] [17]:

Documents delivered electronically in a customer-approved, contractor format but containing no attached electronic semantic meaning. This approach is not recommended nor supported under MBE. Specify when standard digital data can be delivered as electronic paper in a digital form. Electronic paper should include metadata tags, including, but not limited to, data type, system, title, and last modified to assist with document identification, storage, indexing, and key word tagging down to a minimum of three levels of subsections as defined by the program/project. Reuse and/or life-cycle maintenance of materials is not desired.

C. Level 3 (Standard XML Data Descriptions for Digital Data in NASA Standard Format):

For standard XML digital data descriptions to be usable, a common data dictionary has to be referenced by all producers and consumers of digital data as defined by NASA's common data dictionary. If a NASA standard is not applicable, digital data has to reference a common data dictionary as defined by the contractor. A catalog of XML schema data descriptions should exist prior to the delivery of contractor data to NASA. Specify when:

i. The potential for reuse of data exists.
ii. A need exists for interoperability of data described by XML schemas that move between/among NASA Centers and programs/projects with contractors, industry, partners, academia, services, program/project life-cycle states, and/or platforms.
iii. Tagging data according to law, requirements, and classification is needed at the data object level.

D. Level 4 (Digital Data from a Source Repository to a Target Repository in a Program/Project-specified Format):

[16] Zip is a file format used for data compression and archiving. A zip file contains one or more files that have been compressed, to reduce file size, or stored as is. The zip file format permits a number of compression algorithms. Zip files generally use the file extensions ".zip" or ".ZIP."
[17] Enterprise Content Management (ECM) consists of strategies, methods, and tools used to capture, manage, store, preserve, and deliver content and documents related to organizational processes.

Digital data extraction from a source data repository in supplier format, data transformation into a target format, and data loading into a target data repository. Specify when:

i. The potential for reuse of data exists.
ii. A need exists for interoperability of standardized content between/among NASA Centers and programs/projects with contractors, industry, partners, academia, services, program/project life-cycle states, and/or platforms.
iii. A content interoperability management system that conforms to an existing or planned set of NASA information systems and data capabilities that can receive the content.
iv. A need exists for interoperability of database repositories between/among NASA Centers and programs/projects with contractors, industry, partners, academia, services, program/project life-cycle states, and/or platforms.
v. A database-to-database integration approach exists.
vi. Tagging data according to law, policy, or classification is needed at the data object level.

(4) Minimizing customization and adapting external standards can reduce the complexity and would facilitate future upgrades and the exchange of data with external parties. Because process definition is integral to MBE, the native tool flexibility means that even a no-customization solution can still proliferate complexity and inhibit data sharing.

(5) Consolidation of instances of PDM can reduce the visible number of systems while doing little to achieve the critical goals of improved bi-directional sharing of data internally and externally as stated below:

A. For instance, creation of multiple partitions within a single installation in which each partition owner can reproduce their own processes, data structures, and configuration settings will reduce the number of visible “systems” but not guarantee data exchange.
B. Process terms include the definition of the data objects, the flow steps, the descriptors, user roles, and the decision rules.
C. The processes are implemented by configuring elements into flows, so agreement on the base elements is needed to facilitate data sharing and reduce maintenance costs.
D. The depth of agreement on the base elements and flow configuration is the primary mechanism by which interoperability can be achieved.

(6) In lieu of globally defined and rigid process definitions that have to accommodate all types of work, the core definition of critical processes related to interoperability should be pursued. By looking for commonality around collaboration and data sharing, over-specification is avoided and adaptability is encouraged.

(7) Managing product design and facilitating its use also depends on the design data itself being compliant with a set of practices applied outside the tool. Most notably, the configuration, accuracy, identification, and other settings enacted by engineers within the same tool will affect the ability and effort required to share their data with each other; a perfect MBE solution cannot overcome incompatibility choices made at the source. The list of processes that need to be discovered and assessed for interoperability begin outside the MBE tool and extend into manufacturing, procurement, logistics, and mission operations application and systems interfaces.

(8) A program/project manager and the delegated Technical Authority need to address this list of questions that drives process interoperability:

A. How will peer engineers and designers be allowed to share data in support of detailed design?

B. What is sufficient and necessary to define for a specific need (e.g. design, verification, manufacturing):

   i. Part (hardware and software).
   ii. Assembly or subsystem.
   iii. Systems or products.

C. How are parts identified and named to avoid conflict, confusion, and reduce data redundancy?

D. What is the definition of models for a specific purpose (e.g. systems design, part design, envelope, interface checking, thermal and structural analysis, integration, and shrink-wrap)?

E. How are the alternate versions of models related and managed, and what is required to ensure traceability and sharing?

F. What practices and resources reduce the effort required to find, use, and integrate approved part definitions, including common hardware?

G. What state labels, descriptors, and process steps identify the allowed uses, authorized user, and change status of engineering design data during its life cycle (e.g. engineering release, change control, and configuration definition)?

H. What defines a product structure for a given use/audience/life-cycle state, and how is that product structure produced and approved?

APPENDIX H

ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

H.1 Purpose

This Appendix provides a listing of acronyms, abbreviations, and definitions related to this NASA Technical Handbook.

H.2 Acronyms and Abbreviations

A&E	Architect and Engineering
ABCL	as-built configuration list
AD	audit documentation
ADP	acceptance data package
AP	application protocol
API	application programming interface
ASE	airborne support equipment
ASOT	authoritative source of truth
ASSY	assembly
ATBD	algorithm theoretical basic document
ATP	acceptance test procedure
BOM	bill of material
CAD	computer-aided design
CAE	computer-aided engineering
CAGE	Commercial and Government Entity
CAM	computer-aided manufacturing
CCB	Configuration Control Board
CD	compact disc
CDR	Critical Design Review
CDRL	Contractual Deliverable Items List
cg	center of gravity
CDM	configuration and data management
CDMP	Configuration and Data Management Plan
CDMPA	Configuration and Data Management Process Audit
CFR	Code of Federal Regulations
CGM	Computer graphics metafile
CI	configuration item
CID	cable interconnect diagram
CIO	Chief Information Officer

CMO	Configuration Management Organization
COLLADA	COLLAborative Design Activity
COQ	certification of qualification
CORBA	common object request broker architecture
COTS	commercial off the shelf
CPU	central processing unit
CR	change request
CS	computer software
CSA	Configuration Status Accounting
CSCI	computer software configuration item
CSD	computer software documentation
CSV	comma-separated value
CWM	common warehouse metamodel
D	Dimensional
DA	Data Architecture
DAL	data accession list
DCE	digital collaborative environment
DDT&E	design, development, test, and evaluation
DEE	Digital engineering environment
DFAR	Defense FAR
Di	dimensional intelligent
DM	Data Manager
DMO	Data Management Office
DMU	digital mock-up
DoD/DD	Department of Defense
DPD	Data Procurement Document
DR	discrepancy report
DRD	Data Requirements Description
DRL	Data Requirements List
DRM	Data Requirements Manager
DVD	digital versatile disc
DW	data warehouse
DXF	drawing exchange format
EBOM	engineering bills of material
ECAD	electrical computer-aided design
ECM	Enterprise Content Management
ECP	engineering change proposal
EEE	electronic, electrical, and electromechanical
EGSE	electrical ground support equipment
EIA	Electronic Industries Alliance
EMDAL	Engineering models, drawings, and associated lists
EO	engineering order

ePaper	electronic paper
ESB	Enterprise service bus
ETL	Extraction-Transformation-Loading (also EXTL)
EXTL	Extraction-Transformation-Loading (also ETL)
FAR	Federal Acquisition Regulation
FCA	functional configuration audit
FEA	finite element analysis
FEM	finite element method
FFF	form, fit, and function
FFRDC	Federally Funded Research and Development Center
FIPS	Federal Information Processing Standard
FMEA	failure mode effects analysis
FPGA	field programmable gate array
FTP	file transfer protocol
GD&T	geometric dimensioning and tolerancing
GDRM	Global Drawing Requirements Manual
GIF	graphics interchange format
GN&C	guidance, navigation, and control
GOTS	Government off-the-shelf
GPR	Government purpose right
GPU	graphics processing unit
GSE	ground support equipment
GSMAF	Goddard Space Mission Architecture Framework
HDBK	handbook
HR	hazard report
HWCI	hardware configuration item
IAE	index of ancillary equipment
ICD	interface control document
ICWG	Interface Control Working Group
IDL	indentured drawing list
IDP	interface detail product
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGES	Initial Graphics Exchange Specification
INCOSE	International Council on Systems Engineering
IOC	index of components
IOCD	index of configuration documentation
IOTM	index of technical manuals
IP	Internet protocol
IPL	indentured parts list
IS	information systems
ISA	information systems architecture

ISO	International Organization for Standardization
ISP	integrated support plan
ISS	International Space Station
ISSA	Information Support System Architecture
IT	information technology
ITAR	International Traffic in Arms Regulations
IUID	item unique identification
JPEG/JPG	Joint Photographic Experts Group
JPL	Jet Propulsion Laboratory
JT	Jupiter Tessellation
KDP	key decision point
LOTAR	Long-term archiving and retrieval
LOX	liquid oxygen
LR	limited rights
LSI	Lead Systems Integrator
LSP	Launch Services Program
M&S	Modeling and Simulation
MB	model based
MBA	model-based assurance
MBC	model-based compliance
MBD	model-based definition
MBe	model-based engineering
MBE	model-based enterprise
MBI	model-based inspection
MBM	model-based manufacturing
MBOM	manufacturing bill of material
MBSE	model-based systems engineering
MCAD	mechanical computer-aided design
MDA	model-driven architecture
MDE	model-driven engineering
MDM	master data management
MDSE	model-driven software engineering
MEL	master equipment list
MIL	military
MIUL	material identification usage list
MMI	maintenance-managed item
MOF	Meta Object Facility
MOTS	modified off-the-shelf
MOU	Memorandum of Understanding
MRB	Materials Review Board
MRI	master record index
MSFC	Marshall Space Flight Center

MUA	Material Review Board
NA	not applicable
NASA	National Aeronautics and Space Administration
NDA	non-disclosure agreement
NDAF	NASA Data Architecture Framework
NFARS/NFS	NASA FAR Supplement
NIMA	NASA Integrated Model-Centric Architecture
NIST	National Institute of Standards and Technology
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NURBS	non-uniform rational basis spline
OCIO	Office of the Chief Information Officer
OCL	object constraint language
OMG	Object Management Group
OMIT	operation, maintenance, installation, and training
OPR	office of primary responsibility
PCA	physical configuration audit
PCI	product configuration information
PDD	product definition data
PDF	portable document format
PDF/A	Portable document format - archiveable
PDLM	product data and life-cycle management
PDM	product data management
PDR	Preliminary Design Review
PIC	Procurement Information Circular
PLM	product life-cycle management
PMI	part manufacturing information
PMO	Program Management Office
PNG	portable network graphics
POP	period of performance
PS	product structure
PUB	Publication
PWS	Performance Work Statement
QAP	quality assurance provisions
QVT	query/view/transformation
RAM	random access memory
REST	representational state transfer
RFI	Request for Information
RFP	Request for Proposals
RFQ	Request for Quotes
RFV	request for variance
RID	review item discrepancy

RIF/ReqIF™	Requirement Interchange Format
RM	requirements management
RPT	report
RQF	Regulated Qualifications Framework
RR	restricted rights
S&TE	support and test equipment
SBIR	Small Business Innovative Research
SBU	sensitive but unclassified
SDR	System Definition Review
SDT	specification and drawing tree
SE&I	systems engineering and integration
SEMP	Systems Engineering Management Plan
SGML	standard generalized markup language
SGR	Statement of General Requirements
SIE	special inspection equipment
SMA	Safety and Mission Assurance
SME	subject matter expert
SOAP	simple object access protocol
SOR	system of record
SOW	Statement of Work
SP	special publication
SPI	special packaging instructions
SQL	structured query language
SRR	System Requirement Review
SSOT	single source of truth
SSP	Space Shuttle Program
ST	special tooling
STD	Standard
STEP	Standard for the Exchange of Product
SysML™	Systems Modeling Language™
T&I	technology and innovation
TBD	to be determined
TD	technical data
TDLP	technical data package list
TDP	technical data package
TRL	technical readiness level
UID	unique identification
UML	unified modeling language
UR	unlimited rights
URI	uniform research identifier
UUID	universally unique identifier
V&V	verification and validation

VCR	verification compliance report
VDD	version description document
VR	variance request
W3C	World Wide Web Consortium
WBS	work breakdown structure
X3D	extensible 3D
XMI	XML metadata interchange
XML	extensible markup language
XSD	XML schema definition

H.3 Definitions

Authoritative Data: Data that have been designated as valid for specific official programs/projects. The designated data is controlled by processes. (Source: NPD 7120.4, NASA Engineering and Program/Project Management Policy)

Authoritative Source: An application or repository identified as the official source for specific authoritative data.

Computer-Aided Design (CAD): Process of creating engineering designs defined by electronically produced multi-dimensional geometry using special software systems, the tools used by engineers to create geometric-based design definitions represented in a variety of formats, including two-dimensional (2D) drawings, three-dimensional (3D) solid models, envelopes, wireframes, and kinematics and time-based models.

Configuration Management (CM): A management discipline applied over a product's life cycle to provide visibility into and control changes to performance, functionality, and physical characteristics. (Source: NPR 7120.5, NASA Space Flight Program and Project Management Requirements) Also, a technical and management process for establishing and maintaining consistency of a product's functional and physical attributes with its requirements, design, and operational information throughout its life. (Source: SAE EIA-649, Configuration Management Standard)

Contract Data Items List (CDRL): A list of authorized required data requirements for a specific procurement that forms part of the contract/agreement. It is comprised of either a single or multiple DRDs containing data requirements and delivery information. The CDRL is the standard format for identifying potential data requirements in a solicitation and deliverable data requirements in a contract. Use of the CDRL in solicitations is required when a contract will require delivery of data. CDRLs should be linked directly to Statement of Work (SOW) tasks and managed by the Program Management Office (PMO) data manager. Data requirements can also be identified in the contract via Special Contract Clauses (e.g., Federal

Acquisition Regulations/NASA Supplements [NFARS]), which define special data provisions (such as Rights in Data, Warranty, etc.).

The purpose of the CDRL is to provide a standardized method of clearly and unambiguously delineating the Government's minimum essential data needs. The CDRL groups all of the data requirements in a single place rather than having them scattered throughout the solicitation or contract. A DRD is the completed document that defines the data required of a contractor/Offeror and is included in the CDRL. The DRD is used to specifically define the data content, format, and intended use.

Data: The lowest level of abstraction from which information and knowledge are derived. Any collection of recorded facts, numbers, or datum of any nature that can be communicated, stored, and ultimately processed, using business rules, to form useful information. (Source: SAE EIA-649)

- **Authoritative source of truth (ASOT)** - an entity such as a person, governing body, or system that applies expert judgement and rules to proclaim a digital artifact is valid and originates from a legitimate source. (Source: OMG.)
    a. The ASOT for a digital artifact serves as the primary means of ensuring the credibility and coherence of the digital artifact that its creators share with a variety of stakeholders.
    b. It gives stakeholders from diverse organizations and distributed locations the authorization to access, analyze, and use valid digital artifacts from an authoritative source.
    c. The owners of digital environments or the community for digital engineering ecosystems provides stakeholders with an authoritative source of truth that assures confidence in the quality of the digital artifact across disciplines, domains, and life-cycle phases.
- **Single source of truth** (**SSOT**)
    - Architecture - practices structuring information models and associated data schemas such that each data element is mastered (created and/or edited) in only one/single location (no duplication of data or documentation)
        a. Any/all linkages to a data element (in other locations within the relational schema or in external federated databases) are by reference only (pushed/pulled data resides in one source and will update immediately upon source update),
        b. Since all other usages of (locations) the data element merely refer to the primary "source of truth" location, updates to that data element in the primary location are subsequently propagated through the entire system without possibility of a duplicate (non-referenced) value somewhere being forgotten.
        c. Organizations with more than one information system, wishing to implement an SSOT (without modifying all but one master system to

store pointers to other systems for all entities), typically utilize one or more of three supporting technologies, namely:
Enterprise service bus (ESB), Master data management (MDM), or Data warehouse (DW).

- **Authoritative Source of Information/System of Record (SOR)**
    - A system of record is the authoritative data source for a given data element or piece of information.

Data Architecture: Provides an understanding of what information is needed to effectively execute the Enterprise's business processes and provides a framework for effectively managing the Enterprise's information environment. *Note: Data Architecture links information behavior (i.e. accessing, using, and sharing data), information management processes, and information support staff to other aspects of the Enterprise.* (Source: NPR 2830.1, NASA Enterprise Architecture Procedures)

Data Life Cycle: The series of states that a data object can take from its creation to its retirement or destruction; generally, these states represent maturity levels or indicate suitability for, or restrictions on, use.

Data Management: The process used to:

a. Provide the basis for identifying and controlling all types of digital and electronic data.

b. Provide the basis for identifying and controlling data requirements and specifications.

c. Responsively and economically acquire, access, and distribute data needed to develop, manage, operate, and support system products over their product-line life.

d. Manage and dispose data as records.

e. Analyze data use.

f. Ensure data integrity, fidelity, access, security, and proliferation.

g. Enforce data definition standards (naming, security, revisions, CDM).

h. If any of the technical effort is performed by an external contractor, obtain technical data feedback for managing the contracted technical effort.

i. Assess the collection of appropriate technical data and information.

j. Effectively manage authoritative data that defines, describes, analyzes, and characterizes a product life cycle.

k. Ensure consistent, repeatable use of effective MBE processes, best practices, interoperability approaches, methodologies, and traceability. (Source: NPR 7123.1)

Data Model: Identifies the data, their attributes, and relationships or associations with other data. (Source: Department of Defense Directive 8320.03, Unique Identification (UID) Standards for a Net-Centric Department of Defense, March 2007)

Delivery: Applies to the hand-off, which may be physical or virtual in the case of data, at initial delivery of an item during development, for collaboration, in support of reviews, at the time of acceptance, and for subsequent modifications, maintenance, refurbishment, or any other activity that produces new data.

Digital Data: The level of abstraction from which digital (electronically defined) information and knowledge are derived. A collection of recorded facts, numbers, or datum of a digitized object that can be defined, annotated, characterized with non-graphical properties and definition, communicated, stored, and ultimately processed, using business rules, to form useful information. Also, information prepared by electronic means and made available to users by electronic data access, interchange, transfer, or on electronic/magnetic media. (Source: SAE GEIA-HB-649)

Digital Engineering: Engineering performed in a digital collaborative environment which integrates stakeholders providing authoritative sources of data and models seamlessly across organizations and disciplines to support life-cycle activities from concept through disposal.

Digitization: The conversion of analog information into digital form "or as a verb." The act of scanning or converting paper or other descriptive elements into electronic paper such as drawings into machine-readable PDF documents.

Digitalization: The act of transforming paper-based processes and artifacts into the digital and connected world. Unlike digitization, digitalization is the actual "process" of the technologically induced changes within these industries. This process has enabled much of the phenomena today known as the Internet of Things, Industrial Internet, Industry 4.0, big data, machine-to-machine communication, block-chain, cryptocurrencies, etc.

Digital Transformation: The total and overall effect of digitalization. Digitization has enabled the process of digitalization, which resulted in stronger opportunities to transform and change existing business models, socio-economic structures, legal and policy measures, organizational patterns, cultural barriers, etc.

End Item: A product to be delivered under contract as an intact unit or to be assembled, completed, and made ready for use as a unit.

Engineering Release: An action whereby configuration information or an item is officially made available for its intended use. (Source: SAE EIA-649-2)

Governance Model: The framework—principles and structures—through which the Agency manages the mission, roles, and responsibilities. (Source: NPD 1000.0, NASA Governance and Strategic Management Handbook)

Mechatronics: A multidisciplinary field of engineering that includes a combination of systems engineering, mechanical engineering, electrical engineering, telecommunications engineering, control engineering, and computer engineering. As technology advances, the subfields of engineering multiply and adapt. Mechatronics' aim is a design process that unifies these subfields.

Metadata: Data about data, properties (title, document number, creation date, etc.) used to identify or define a data item. (Source: SAE EIA-649)

Model: A description or representation of a system, entity, phenomena, or process. (Source: NASA-STD-7009, Standard for Models and Simulations)

Modeling (verb): The physical activity of creating an abstract or digital object that represents a system, entity, phenomena, or process. (Source: NASA-STD-7009, Standard for Models and Simulations)

Model Based: An annotated model and its associated data elements that define a product, which can be used effectively without a drawing. It describes a technology approach where rigorous visual modeling principles and techniques form the technical foundation for an engineering or development process to increase its efficiency and productivity. The model is the source authority that drives all engineering activities.

Model-Based Engineering Framework: The set of processes that defines and utilizes associated information used to manage and execute the entire life cycle of product data from its conception, through design, test, qualification, and manufacturing, to service and disposal and integrates definition and product development data, processes (elements), tools, and business and analytical systems to provide users with a digital product information backbone for defining NASA programs/projects.

Model-Based Engineering Framework System: A combination and interoperability connection of systems utilizing information technology applications, user-defined apps, and processes that implement the management of digital product and systems data within the extended enterprise (inclusive of Center to Center and inclusive of suppliers, partners, and primes) across the product life cycle.

Model-Based Manufacturing (MBM): Defines the desired end target state of the earlier defined model based definition. Test and validation for compliance (model-based compliance [MBC]) come into play to ensure manufacturing is executing to the proper and correct requirements, materials are developed or assembled per the proper specification, and process steps for formulation are followed and executed properly.

Model-Based Systems Engineering (MBSE): The formalized application of modeling to support system requirements, design, definition, analysis, verification, and validation activities beginning in the conceptual design phase and continuing throughout development and later life-cycle phases. (Source: International Council on Systems Engineering (INCOSE), *Systems Engineering Vision 2020*, Version 2.03, TP-2004-004-02, September 2007)

Models-Based Approach: An approach to developmental engineering in which the design and its associated analyses, specifications, etc., are created, used, and managed as a non-document digital data object (or multiple linked objects); different formats exist to support different engineering domains, and these divergent needs and data differences impact interoperability, data integrity, and engineering data management.

Model-Driven Software Engineering (MDSE): A software development methodology that focuses on creating and exploiting domain models, which are conceptual models of all the topics related to a specific problem. Hence, it highlights and aims abstract representations of the knowledge and activities that govern a particular application domain, rather than the computing (i.e. algorithmic) concepts.

Product: A part of a system consisting of end products that perform operational functions and enabling products that perform life-cycle services related to the end product or a result of the technical efforts in the form of a work product (e.g. plan, baseline, or test result). (Source: NPR 7123.1) Also, the following:

a. Hardware, e.g. engine mechanical part.
b. Software, e.g. computer program or model.
c. Processed materials, e.g. a lubricant.
d. Facilities, e.g. a laboratory or machine shop.

(Source: SAE EIA-649-2)

Product Breakdown Structure: A hierarchical view of the relationship of products and component products. (Source: NPD 7120.4, NASA Engineering and Program/Project Management Policy)

Product Data and Life-Cycle Management (PDLM): NASA's strategic business approach that consists of both PDM (product data management) and PLM (product life-cycle management). PDLM applies not only to a mechanism to store and retrieve data but also to manage the data over the product development life cycle. PDLM leverages a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition data/information across the extended enterprise from concept to end of life.

Product Data Management (PDM): The framework that enables organizations to manage and control engineering and technical information, specifically data surrounding the product's design, definition, and related engineering, manufacturing, and logistics processes and is a key element of PLM. *Note: From the product perspective, PDM organizes data required for design evolution, tracks versions and configurations of evolving design concepts, and manages archived data and other product-specific information. PDM tools provide access to product structures and other engineering data such as requirements, as-built data, and safety and mission assurance data. From the process perspective, PDM systems offer the capability to orchestrate controlled procedural events such as design reviews, approvals, product releases, and configuration audits.* (Source: NPD 7120.4)

Product Definition Data (PDD): Data that defines the product's requirements, documents the product attributes, and is the authoritative source for configuration management of the product. (Source: Adapted from SAE EIA-649)

Product Life Cycle: A series of states that generally defines the maturity level of a product and correlates with specific uses or users. Commonly, each state is represented by an agreed-to collection of information that identifies and establishes the attributes of a product at a point in time and that serves as the basis for defining change. *Note: A product's life cycle begins with a concept and ends with disposal.*

Product Life-Cycle Management (PLM): A strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition data/information across the extended enterprise from concept to end of life. *Note: PLM integrates people/organizations, processes, and information.* In product-dominated endeavors, PLM serves as the information backbone that extends outside the enterprise. PLM implementations may be composed of multiple elements, including foundation technologies and standards (e.g. Extensible Markup Language (XML)), visualization, collaboration, and enterprise application integration), information authoring tools (e.g. mechanical computer-aided design, electrical computer-aided design, and technical publishing), core functions (e.g. data vaults, document and content management, workflow, and program/project management), functional applications (e.g. CDM), and business solutions built on the other elements. (Source: NPD 7120.4)

Simulation: The imitation of the characteristics of a system, entity, phenomena, or process using a computational model. (Source: NASA-STD-7009)

Software: (1) All or part of the programs, procedures, rules, and associated information of an information processing system; or (2) computer programs, procedures, and possibly associated information and data pertaining to the operation of a computer system. *Note: The definition of software is independent of the media on which the software is stored or the device in which the software executes (such as a programmable logic device).* (Source: SAE EIA-649-2) Also, computer programs, procedures, scripts, rules, and associated documentation and data pertaining to the development and operation of a computer system. This definition applies to software developed by NASA, software developed for NASA, COTS software, Government-off-the-shelf (GOTS) software, modified-off-the-shelf (MOTS) software, reused software, auto-generated code, embedded software, the software executed on processors embedded in Programmable Logic Devices (see NASA-HDBK-4008), and open-source software components. *Note 1: Only for purposes of the NASA Software Release program, the term software, as redefined in NPR 2210.1,* Release of NASA Software, *does not include computer databases or software documentation. Note 2: Definitions for the terms COTS, GOTS, heritage software, MOTS, legacy software, software reuse, and classes of software are provided in NPR 7150.2.* (Source: NPD 7120.4)

Virtual Database: A container for components used to integrate data from multiple data sources so that they can be accessed in an integrated manner through a single, uniform application programming interface (API). It contains models, which define the structural characteristics of data sources, views, and Web services.

APPENDIX I

RATIONALE AND INTRODUCTION TO THE DIGITAL ENGINEERING ENVIRONMENT

I.1 RATIONALE

The creation, usage, and management of digital product-related data used in cradle-to-grave life cycles are daily events at NASA. The scale and complexity of the data now required for model and program definition continues to grow not only for product definition but also with regard to the communication of "smart and intelligent" digital data to and from all program participants. NASA programs and projects are beginning to use the digital models as the authoritative understanding of the system, avoiding expensive testing which is no longer a single site activity but now meaning collaborative work.

In light of the current climate of change, whereas NASA prime contractors and partners are taking a more active role as "System Integrators," NASA has identified the need to alter the current acquisition process to that as a model-based acquisition process—Center-to-Center and Center-to-commercial supplier product development, collaboration, and interoperability processes to remain relevant by leveraging model-based techniques, benefits, and collaborative technologies. Many current revisions of NASA's Technical Handbooks, although full of sound engineering principles, do not address today's digital environment or address MBE practices.

It is incumbent on NASA to develop and adopt new agile approaches achieving greater performance and affordability to meet the Agency's current and future challenges. Without sustained efforts funded with predictable investment to restore agile effectiveness and modernization, we will rapidly lose our technological advantages, resulting in an organization that has legacy methods and systems irrelevant to the challenges confronting us. To meet the Agency's goals and objectives, we must modernize our thinking and practices to develop systems and processes that prioritize the speed of development and delivery enabling our success.

The integration of the information in these models is a challenge, and the size of the data sets produced by some engineering models strains the limits of some data management and data transfer systems. New programs need to consider digital elements, including the authoritative data source repository, shared access, and storage and retrieval mechanisms not only internal to NASA but also to primes/partners to respond in meeting these challenges. Therefore, the need to address the acquisition framework must be updated to reflect the model-based environment that depicts NASA.

I.2 INTRODUCTION

NASA must promote our use of various digital representations of systems and components and the use of digital artifacts as a technical means of communication across the diverse set of stakeholders. The MBE strategy addresses a range of disciplines involved with the acquisition and procurement of systems; and it encourages innovation in the way we design, build, test, deploy, operate, maintain, and sustain our systems and how we train and shape our workforces to use these practices.

The way that we do this is by incorporating the use of digital computing, analytical capabilities, and new technologies to conduct engineering in more integrated virtual environments increasing customer and vendor engagement, improving collaboration response timelines, fostering technology infusion, reducing documentation cost, and positively affecting operational and sustainment affordability. These comprehensive engineering environments will enable NASA internally and with its industry partners to evolve designs at the conceptual phase, reducing the need for expensive physical mock-ups, premature design freezing, and physical development testing.

This NASA Technical Handbook describes the digital engineering vision to modernize how the Agency designs, develops, delivers, operates, and sustains systems. NASA defines digital engineering as an integrated digital approach that uses authoritative sources of system data and models as a continuum across organizations and disciplines to support life-cycle activities from concept through disposal and the beginnings of the "what" that are necessary to foster the use of digital engineering practices. This NASA Technical Handbook intends to lay out the foundation for those implementing the practices who must further develop their "how"—the implementation steps necessary to apply digital engineering in each of their enterprises and specific programs/projects. The Centers and programs/projects should develop corresponding digital engineering implementation plans to ensure the Agency advances this timely and imperative effort. OCE will develop new and/or update existing Agency policies that support realization of digital engineering goals (e.g. data rights, intellectual property), develop standard contract language for RFPs that encourages model-centric interaction between industry and government, and support standards development to support digital engineering goals.

While this NASA Technical Handbook may not cover all aspects and topics of MBE, references are provided to the appropriate sources for deeper study and information.

This NASA Technical Handbook addresses:

- A high-level overview of MBE that serves as the core domain and environment from which subsequent model-based activities (such as manufacturing, acquisition, etc.) will be based upon.

- General guidance to adapt the engineering methods needed to collaborate internally as well as externally to implement model-based product/data acquisition requirements in accordance with NPR 7120.5.

- Architectural processes and impacts when determining the need to implement a model-based environment and intending to utilize topics and methods such as MBSE, MBE, MBM, and PDLM.

- Reference and inclusion of current NASA acquisition (contractual language, e.g. SOW/PWS clauses, DRDs, etc.) that will be updated or new ones created to provide a foundation framework that supports a collaborative MBE approach.

- Model interoperability standards within NASA development domains and integration from Center to Center and Center to commercial suppliers.

APPENDIX J

MODEL-BASED ENGINEERING (MBE) PLAN

J.1 PURPOSE

The purpose of an MBE Plan is to document agreement among the program manager and various providers of MBE services on how the identified MBE capabilities will be provided. For single-project or tightly coupled programs (as defined in NPR 7120.5), a single program-wide Plan should be produced. A variety of program and project documents, project data, and process requirements will need to be synchronized with this Plan and with the provision of IT-related capabilities, services, and infrastructure.

J.2 MBE PLAN DEVELOPMENT GUIDELINES

Table 9, MBE Plan Development Guidelines, is a recommended guideline for the development of the MBE framework and element information that is to be captured in the MBE Plan.

Table 9—MBE Plan Development Guidelines

Preliminary PDLM Plan Signed and Released

	Formulation				Implementation		
MBE Elements	**Pre-Phase A** Concept Studies	**Phase A** Concept & Technology Development	**Phase B** Prelim Design & Technology Completion	**Phase C** Final Design & Fabrication	**Phase D** Sys Assembly, Integration & Test, Launch & Checkout	**Phase E** Operation & Sustainment	**Phase F** Closeout
	KDP 0	**KDP I**	**KDP II**	**KDP III**	**KDP IV**	**KDP V**	**KDP VI**
Security Architecture	Preliminary	Preliminary	Baseline	Update	Update	Update	
Information Support System Architecture	Preliminary	Preliminary	Baseline	Update	Update	Update	
Data Architecture	Preliminary	Preliminary	Baseline	Update	Update	Update	
Process Architecture	Preliminary	Preliminary	Baseline	Update	Update	Update	
Requirements Management	Preliminary	Baseline	Update	Update			
Configuration Management	*	Baseline	Update	Update	Update	Update	Update
Risk Management	*	Preliminary	Baseline	Update	Update	Update	

	Formulation				Implementation		
MBE Elements	**Pre-Phase A** Concept Studies	**Phase A** Concept & Technology Development	**Phase B** Prelim Design & Technology Completion	**Phase C** Final Design & Fabrication	**Phase D** Sys Assembly, Int &Test, Launch & Checkout	**Phase E** Operation & Sustainment	**Phase F** Closeout
	KDP 0	**KDP I**	**KDP II**	**KDP III**	**KDP IV**	**KDP V**	**KDP VI**
Product Data Management	*	**Preliminary**	**Baseline**	**Update**	**Update**	**Update**	**Update**
Parts Management	*	*	**Preliminary**	**Baseline**	**Update**	**Update**	**Update**
CAD Data Management	*	**Preliminary**	**Baseline**	**Update**	**Update**	**Update**	
Product Structure (Bill of Material)	*	**Preliminary**	**Preliminary**	**Baseline**	**Update**	**Update**	
Models-Based Design, including Models and Simulations	**Preliminary**	**Preliminary**	**Baseline**	**Update**	**Update**	**Update**	
Digital Data Standards and Contract Language	**Preliminary**	**Preliminary**	**Baseline**	**Update**	**Update**		
Interoper-ability and Sustainability	**Preliminary**	**Preliminary**	**Baseline**	**Update**	**Update**	**Update**	

*These items are to be addressed in the MBE Plan but are expected to be an in-work or to-be-determined state with planned resolution.

J.3 MBE PLAN DEVELOPMENT

MBE Plans reflect the requirements for specific MBE capabilities to support the specific program/project's scope, document the choices among alternative delivery mechanisms and providers, and discuss in detail reliance on IT infrastructure and services. An MBE Plan defines the scope of each Center's responsibilities, the implementation approach, the environment in which the program and its projects' MBE solution(s) operates, and timing for implementation of the MBE solution and associated processes, data, elements, attributes, and formats. The content of an MBE Plan is affected by both the program/project's phasing and by current and planned changes to the IT used to implement MBE (e.g. updates and capabilities committed to by MBE tool providers). The Plan should be treated as a formally controlled program document.

Concurrence with the Plan is noted by signatures by the program manager, the Mission Directorate Associate Administrator, and providers of MBE capabilities such as Center Directors and the Mission Directorates. Project managers for tightly coupled programs are required to sign the Plan. The Center Directors' concurrence with an MBE Plan documents their commitment to provide required Center resources to support the program/project as articulated in the MBE Plan. The Plan needs to be updated annually or at a major KDP. In the case of product life cycle, the Plan needs to be updated through KDP F (close out/archival of data). At KDP C, the programs/projects are beginning to understand the data roadmap (Architecture) and inter-dependencies between the suppliers and NASA.

Elements of a Plan are described as follows:

a. Title page—Document number, document title, release state, and release date.
b. Revision and history—Revision level, change number, description, and release date.
c. Signature page.
d. Table of Contents.
e. Preface.
    (1) P.1 Purpose of document.
    (2) P.2 Applicability and scope.
    (3) P.3 Change authority.
    (4) P.4 Applicable and reference documents.
f. Body of the document (see Table 10.)

Table 10, MBE Plan Section Development, lists the MBE Plan sections, identifies the MBE contributors, and lists the agreements that should be reached for each MBE area, followed by detailed descriptions of data to include in each section. All sections of the MBE Plan are required. If an extensive discussion is required, the section content may be captured in detail in a stand-alone document referenced appropriately and summarized in the section. If the material has been covered in another approved programmatic document, the source document and the appropriate sections, paragraphs, or pages should be indicated. If a section is not applicable due to the nature of the program or project, include the phrase "Not applicable" in that section and provide the rationale. Use section 2.2 to indicate waivers or deviations for compliance with the specific requirements of this NPR and identify the source authority documents.

Table 10—MBE Plan Section Development

Section No.	MBE Plan Section	Responsibility/Competency	Action
1.0	PROGRAM/PROJECT OVERVIEW[1]	Program/Project Management; Center(s) Management; Center(s) CIO; Center(s) Engineering Department	Contributors agree on the stated performance objectives for the Program/Project MBE.
1.1	Introduction		Briefly describe the goals of the program and the organizational structure of the program, its projects, and project elements. Also, provide a context diagram identifying the program and relationships to each project and element, and identify program/project documents that will aid readers in understanding the scope, goals, and schedules of the content of this Plan.
1.2	Objectives		State the specific objectives and high-level performance goals levied on the program and its projects for MBE.
1.3	Solution Summary		Summarize the content of this Plan: which specific solutions will be used by which program or project elements and for what MBE functions, clarifying use by product life cycle and user community, and identifying approximate maturity levels. If needed beyond the content in the body of this Plan, refer to associated documents that describe details of the solution elements.
1.4	Assumptions, Limitations, and Constraints		List any assumptions affecting this solution such as upgrades, software licenses, access control, network services, contract provisions/award, or other similar matters. If this Plan addresses a subset of all the requirements expected for MBE support through the life of a program or project, indicate that scope.

Section No.	MBE Plan Section	Responsibility/Competency		Action
1.5	Responsible Organizations, Governance, and Plan Update Timing			Define responsible organizations and their roles. For example, depending on the scope of the program/project, this responsibility may be assigned to a responsible party within program planning and control, or there may be a separate organization such as an information systems office. Identify the governing mechanisms (including processes, boards/panels) through which service capability requests and other decisions related to the requirements in this Plan or their implementation will be approved. Clarify the scale or scope of requests or changes that require formal approval and potentially lead to an update of this Plan. Identify the program or project document describing the change control process for this Plan. Address timing of the preliminary release, baseline, and updates to the program MBE Plan. This timing should recognize that the maturity of the Plan is affected by both the program's phasing and by current and planned changes to the information technology used to implement MBE (e.g. updates and capabilities committed to by MBE tool providers).
2.0	PROGRAM/PROJECT MBE REQUIREMENTS TRACEABILITY	MBE Program/Project Manager and Delegated Technical Authority(s)		Requirement Traceability Matrix identifies compliance that the MBE System meets the requirements in the contract DRD.
2.1	Requirements Traceability Matrix			Identify the specific paragraphs section 4.0, MBE Implementation Details, in this table that address compliance with the guidance in Table 9, Data Architecture. For any Data Architecture guidelines that cannot be mapped to an implementation plan

Section No.	MBE Plan Section	Responsibility/Competency	Action
			detail in section 4.0, describe whether they do not apply or are to be achieved through future work. Identify the specific paragraphs in section 4.0 that address compliance with the guidance in Table 9, Process Architecture. For any Table 9 Process Architecture guidelines that cannot be mapped to an implementation plan detail in section 4.0, describe whether they do not apply or are to be achieved through future work.
2.2	"Do-Not-Apply" Justifications		Identify deviations and waivers to the NASA directive requirements and the source authority for that identified. Justify the exclusion of a requirement from any NASA directive. Justify the exclusion of any guidance from Process Architecture in Table 9.
2.3	Future Work Discussion		Indicate activities or decisions that are in work or not yet under way at the time this Plan is approved but that will affect the MBE Plan. A future work item here does not substitute for an update to this Plan but does allow affected parties to be aware of upcoming issues. Discuss the rationale and nature of the future work related to Data Architecture in Table 9. Discuss the rationale and nature of the future work related to Process Architecture in Table 9.
3.0	MBE STRATEGY	MBE Program/Project Manager and Delegated Technical Authority(ies)	Work with engineering and stakeholders to define MBE needs. Determine data exchange between disparate MBEs (if needed) and determine if gap analysis to resolve issues is needed.
3.1	MBE Strategy		Describe the overarching strategy to be used by this program and associated projects to meet the goals of

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Section No.	MBE Plan Section	Responsibility/Competency	Action
			NASA directives. Describe how the strategy affects the adoption and deployment of MBE concepts and practices. Identify Center and Agency IT initiatives such as network updates, program-specific IT solutions, and MBE consolidation, and discuss how the MBE strategy aligns with these initiatives.
3.2	Product Data Management Approach		Discuss how product data and product definition will be managed for the program and projects covered under this Plan. Identify dependencies and barriers that must be addressed for full implementation of product data management for this program and its projects.
3.3	Product Life-Cycle Management Approach		Discuss how product life-cycle management will be conducted for the program and projects covered under this Plan. Identify dependencies and barriers that must be addressed for full implementation of product life-cycle management for this program and its projects.
4.0	MBE IMPLEMENTATION DETAILS	MBE Process Lead	Program/project and Center organizations review, modify, and determine if gap analysis is needed for existing Center processes for use by the program/project
4.1	Processes		**Process Identification**: Describe processes to be supported in MBE solutions at involved Centers or sites and the projects/elements that will be using those processes. Refer to relevant documents that describe desktop instructions and associated tools for the implementation of work processes. **Functional Support**:

Section No.	MBE Plan Section	Responsibility/Competency	Action
			Define specific process support and its linkage to automated MBE solutions for engineering change control and release management, data management, configuration management, and program/project needs for decision support, reviews, design and systems engineering, and operations and sustaining tasks. **Monitoring and Performance Metrics**: Discuss the management tools available to monitor process performance and issues such as time in queue, mean flow time for reviews, release rates, average number of changes in process, and number of rejected submissions. **Data Integrity Processes**: Identify key PDD-related processes associated with ensuring integrity of data and with ensuring authoritative data are properly and efficiently managed. **Data Exchange Processes**: Identify data exchange processes, discuss the timing and nature of their use and involved users, and the state of process implementation or maturity. Identify associated pre- and post-processing for PDD associated with data exchanges (e.g. from design to assembly) and the parties responsible for such processing. Identify cases where standard processes are not yet in place or where exceptions have been made and explain the reasoning for any exceptions.
4.2	User Communities	MBE Program/Project Manager and Delegated Technical Authority(ies)	Determines the users and their locations of the MBE system(s).
			Identify the user communities, their physical location, their program/project assignments, and their primary responsibilities.

Section No.	MBE Plan Section	Responsibility/Competency	Action
4.3	MBE Tools	MBE Tool Implementation Lead	Works with Center CIO to identify existing MBE system/tools and with program/project to determine if current tools will satisfy program/project needs.
			Identify the MBE tools and specific applications within those tools to be used and the NASA suppliers of those tools. Map these tools to the user communities defined in 4.2 of this table.
4.4	Process Mapping	MBE Process Lead	Identifies functional organizational processes that are to be used by the program/project and determines if gap analysis is needed. Also, identifies the interfaces between related processes (e.g. program/project CDM to Center CDM).
			Map the processes from section 4.1 to the user communities defined in section 4.2 in this table. Map the processes from section 4.1 to the tool in section 4.3 in this table. If relevant processes are defined in other documents, provide the document numbers, document titles, and locations of these documents.
4.5	Data Architecture	MBE Program/Project Manager and Delegated Technical Authority(ies)	The NASA Chief Engineer provides the program/project with its MBE architecture document(s) to assure program/project MBE needs will be met. MBE program/project manager and delegated Technical Authority(ies) identify data relationships between different object types.

Section No.	MBE Plan Section	Responsibility/Competency	Action
			If Data Architecture is addressed in stand-alone program or project documents, identify those documents here, including the status of such documents and future plans regarding their content and applicability. Depending upon the scale and scope of the program and its projects, not all aspects of Data Architecture need to be addressed independently; summarize relevant content from other program materials as it relates to the Data Architecture for product life cycle and PDD. Identify Data Architecture requirements being imposed upon the MBE solution elements to support interoperability, data exchange, metadata, and work practices.
4.6	Product Breakdown Structure (highest level representation of products used to develop WBS)	MBE Process Lead	Determines program/project product breakdown structure needs; determines if current architecture will meet needs.
			Explain how the various levels of product breakdown structure(s) for the system end products, their subsystems, and the supporting or enabling products will be represented and how in-house and contractor data will be integrated into the different product breakdown structures (or bills of materials) needed across the program life cycle. Summarize how product breakdown structures (or bills of materials) will be used in the program and its projects. Discuss how the MBE implementation approach described in this NASA Technical Handbook will support multiple product breakdown structures being available simultaneously across product life cycles and program/project milestones. Discuss how software and hardware elements of product breakdown structure will be linked in support of

Section No.	MBE Plan Section	Responsibility/Competency	Action
			program/project needs and the effect of those requirements on this solution.
4.7	Specialized Data Type Process	MBE Process Lead	Identifies the MBE data objects and associated attributes needed to support the programs/projects. Determines what the data interoperability requirements are.
			Document intentions regarding when to use specialized data types such as 3D CAD, 2D CAD, models, simulations, or specialized design tools (e.g. to conduct simulations of product performance, control design definition for manufacturing, for acceptance check on physical hardware, for visualization and training, and for engineering analysis and modeling). Describe which, and for what purposes, CAD tools will be used by program and project elements, including contractors and partners. Discuss how the elements of NASA's MBE CAD interoperability requirements will be applied over the life cycle of the program. Identify additional internal or external standards, practices, settings, and supporting tools to be used (e.g. for model checking, conformance, analysis reuse, and data exchange) and identify parties responsible for such determinations. Discuss how the elements of NASA-STD-7009, Standard for Models and Simulations, will be applied to product data management. Identify additional internal or external standards, practices, or program documents that cover modeling and simulation data handling, and identify parties responsible for such determinations. Identify the standards to be used for part identification. Identify responsible parties and processes for addressing conflicts and issues around CAD file naming, part identification, and

Section No.	MBE Plan Section	Responsibility/Competency	Action
			reconciliation of issues emerging from use of common hardware CAD files and integration of CAD files across Centers, program elements, contractors, and partners. Define policies for identifying the handling of models, simulations, CAD design documents that are proprietary, intellectual property, or designated as sensitive but unclassified (SBU). Identify the program/project data or documents that the CAD producer is to provide in addition to the CAD object to assure full PDD such as parts lists, materials specifications, or acceptance testing specifications and where such material will be maintained.
4.8	Specialized Libraries and Part Data	MBE Process Lead	Determines what types of libraries and part objects are required to support the program/project. Defines the part and document identification schema.
			Describe how elements of the MBE solution will be used to avoid or reduce the occurrence of duplicate or multiple part numbers and designations for an identical physical part. Describe how the program/project will work with the organizations responsible for shared part definition libraries, common model and simulation libraries, and CAD libraries (whether internal or external to the program) to ensure approved practices are followed for such matters as use, naming, and substitutes/alternatives.

Section No.	MBE Plan Section	Responsibility/Competency	Action
4.9	Engineering Release, Configuration Management, and Change Control Processes	MBE Process Lead	Works with CM organization to define change control process. Defines and documents as part of the MBE Plan what product data is released, when that product data is to be released, the events that necessitate product data change, and the processes that provide the visibility of the product data configuration life cycle for internally and externally produced product data.
			Identify existing (or describe the requirements for modifications to) engineering release and delivery-of-items processes to support program/project needs and interoperability across Centers, program elements, contractors, and partners. Include the identified solutions (or requested modifications) to provide visibility of the life cycle, maturity, and change status of PDD (such as 3D CAD models) and other engineering models across the program/project life cycle. Identify the program/project-specific documents that address engineering release, change control, and configuration management and summarize their content, including contractor configuration management, as required by SAE EIA-649-2, NASA Configuration Management Requirements for NASA Enterprises.
4.10	Data Management Process	MBE Process Lead	Identifies the MBE data objects and associated attributes needed to support the programs/projects.

Section No.	MBE Plan Section	Responsibility/Competency	Action
			Identify the program/project-specific documents that address product-related data management with particular attention to PDD and summarize their content. Define reports, analyses, data sets, models, simulations, and documents (especially those leading up to a design, e.g. stress analyses, thermal, loads, dynamics) that will be generated for program management, troubleshooting, and problem resolution. Define a set of authoritative requirements and data that represent the various stages of the products (e.g. as designed, as built, as delivered, as maintained) that will represent the architecture of the product at all stages. Describe PDD data delivery sources, processes, usage, and access rights, including contractor-originated data across the entire project life cycle. Identify the source and summarize relevant content from the program's records plans as required by NPD 1440.6, NASA Records Management, and NPR 1441.1, NASA Records Retention Schedules, and include contractor records content or identify source documents and their locations.
4.11	Information Security	MBE Program/Project Manager and Delegated Technical Authority(ies)	Works with Center CIO to identify applicable security plans for applications and systems to be used.
			Identify party responsible for the IT security plan for the applications/systems to be used. Discuss any intended revisions to support the specific program/project needs, their timing, and status.

Section No.	MBE Plan Section	Responsibility/Competency	Action
	APPENDICES		Allows for the inclusion of supporting material such as concepts of operation, user scenarios, glossaries, and the like.

APPENDIX K

REFERENCES

K.1 Purpose and/or Scope

This Appendix provides additional guidance available in the references below.

K.2 References

Reference documents may be accessed at https://standards.nasa.gov or obtained directly from the Standards Developing Body or other document distributors. When not available from these sources, information for obtaining the document is provided. The latest issuances of cited documents apply unless specific versions are designated. The following references are recommended for further guidance[18]:

a. MBSE

NASA Models-Based Systems Engineering Group (The MBSE Community of Practice has moved to a new URL: https://nen.nasa.gov/web/mbse)

INCOSE (International Council on Systems Engineering) (www.incose.org)

INCOSE (2007) MBSE Initiative Presentation International Council on Systems Engineering (INCOSE), *Systems Engineering Vision 2020*, Version 2.03, TP-2004-004-02, September 2007.

Requirements Exchange: ReqIF™ Requirement Interchange Format - Object Management Group™ standard (http://www.omg.org/spec/ReqIF/)

b. CAD Data Management

ASME Y14.41, Digital Product Definition Data Practices, Engineering Product Definition and Related Documentation Practices

ASME Y14.47, Model Organization Practices - Engineering Product Definition and Related Documentation Practices

PROSTEP AG, White Paper, “3D Formats in the Field of Engineering – A

[18] If Web links are not accessible from this document, copy and paste the Web address into the address block after accessing the Internet.

Comparison (https://www.3dpdf.com/index.php?id=1952&L=1)

c. Data Interoperability

Data and Information Policy (http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/)

M-13-13, Open Data Policy - Managing Information as an Asset (https://policy.cio.gov/open-data/)

ISO 8879, Information processing – Text and office systems – Standard Generalized Markup Language (SGML)

ISO 16792, Technical product documentation—Digital product definition data practices

ISO/IEC 15288, Systems and software engineering – System life cycle processes

ISO/IEC 19501, Information technology – Open Distributed Processing – Unified Modeling Language (UML)

ISO/IEC 19502, Information technology – Meta Object Facility (MOF)

ISO/IEC 19503, Information technology – XML Metadata Interchange (XMI)

ISO/IEC 24765:2009, Systems and software engineering - Vocabulary

ISO/IEC/IEEE 42010, Systems and software engineering – Architecture description

d. Contract Language

48 CFR § 252.227-7013 - Rights in technical data - Noncommercial items

48 CFR § 252.227-7014, Rights in Noncommercial Computer Software and Noncommercial Computer Software Documentation

48 CFR § 252.227-7015, Technical data - Commercial items

48 CFR § 252.227-7025, Limitations on the Use or Disclosure of Government-Furnished Information Marked with Restrictive Legends

48 CFR § 252.227-7037, Validation of Restrictive Markings on Technical Data

48 CFR § 227.7103-6, Contract Clauses

48 CFR § 227.7103-7, Use and Non-disclosure Agreement

48 CFR § 227.7103-13, Government Right to Review, Verify, Challenge, and Validate Asserted Restrictions

ISO 10303-203, Industrial automation systems and integration — Product data representation and exchange — Part 203: Application protocol: Configuration controlled 3D design of mechanical parts and assemblies

ISO 10303-209, Industrial automation systems and integration - Product data representation and exchange - Part 209: Application protocol: Multidisciplinary analysis and design

ISO 10303-210, Industrial automation systems and integration - Product data representation and exchange - Part 210: Application protocol: Electronic assembly, interconnect and packaging design

ISO 10303-214, Industrial Automation Systems and Integration - Product Data Representation and Exchange - Part 214: Application Protocol: Core Data for Automotive Mechanical Design Processes

ISO 10303-233, Industrial automation systems and integration - Product data representation and exchange - Part 233: Application protocol: Systems engineering

ISO 10303-238, Standard for the Exchange of Product (STEP) Model Data, PART 238: Application interpreted model for computer numeric controllers

ISO 10303-239, Industrial automation systems and integration - Product data representation and exchange - Part 239: Application protocol: Product life cycle support

ISO 10303-242, Industrial automation systems and integration – Product data representation and exchange – Part 242: Application protocol: Managed model-based 3D engineering

NIST 800 Series Publications

e. Contract Language for Defining Data Interoperability

DFARS 252.227-7026, Deferred Delivery of Technical Data or Computer Software

DFARS 252.227-7027, Deferred Ordering of Technical Data or Computer Software

48 CFR § 52.227-11, Patent Rights - Ownership by the Contractor

48 CFR § 52-227-12, Reserved

48 CFR § 52-227-13, Patent Rights-Ownership by the Government

48 CFR § 52.227-14, Alternates II and III, Rights in Data—General

48 CFR § 52-227-15, Representation of Limited Rights Data and Restricted Computer Software

48 CFR § 52.227-16, Additional Data Requirements

48 CFR § 52-227-17, Rights in Data-Special Works

48 CFR § 52-227-18, Rights in Data-Existing Works

48 CFR § 52-227-19, Commercial Computer Software License

48 CFR § 52.227-20, Rights in Data-SBIR Program

f. Exchanging and Distributing 3D Models

ISO 10303, STEP (Standard for the Exchange of Product model data) - ISO global standard

ISO 14306, Industrial automation systems and integration -- JT file format specification for 3D visualization

ISO 14739-1, Document management — 3D use of Product Representation Compact (PRC) format, Part 1: PRC 10001

ISO 32000-1:2008, Document Management – Portable document format – Part I: PDF 1.7 – First edition

g. Other Neutral Formats not listed in Table 3

DXF (Drawing Exchange Format) – AutoDesk

ANS US PRO/IPO-100-1996, IGES (Initial Graphics Exchange Specification), Version 5.3, United States Product Data Association (US PRO). Note: No further work is being done on this standard, and US PRO closed in 2006.

ISO/IEC 8632:1999, CGM (Computer Graphics Metafile) (www.iso.org)

ISO/IEC 11578:1996, Information Technology – Open Systems Interconnection – Remote Procedure Call (RPC)

ISO/IEC 19776-2:2011, Information technology - Computer graphics, image processing and environmental data representation - Extensible 3D (X3D) encodings - Part 2: Classic VRML encoding - COLLADA (Collaborative Design Activity) – Khronous Group, collada.org, X3D (eXtensible 3D)(www.iso.org)

h. Institute of Electrical and Electronics Engineers (IEEE)

IEEE 24765, Systems and software engineering — Vocabulary

i. Federal

FIPS PUB 140-2, Security Requirements for Cryptographic Modules

j. Department of Defense (DoD)

DoD Directive 8320.03, Unique Identification (UID) Standards for a Net-Centric Department of Defense

MIL-STD-130, Department of Defense Standard Practices, Identification Marking of U.S. Military Property

MIL-STD-31000, Technical Data Packages

MIL-HDBK-61A, Configuration Management Guidance

DD Form 250, Material Inspection and Receiving Report

DD Form 1149, Requisition and Invoice/Shipping Document

k. NASA

NPD 1000.0, NASA Governance and Strategic Management Handbook

NPD 1440.6, NASA Records Management

NPD 2810.1, NASA Information Security Policy

NPD 7120.4, NASA Engineering and Program/Project Management Policy

NPR 1441.1, NASA Records Management Program Requirements

NPR 2210.1, Release of NASA Software

NPR 2800.1, Managing Information Technology

NPR 2810.1, Security of Information Technology

NPR 2830.1, NASA Enterprise Architecture Procedures

NPR 7120.5, NASA Space Flight Program and Project Management Requirements

NPR 7123.1, NASA Systems Engineering Processes and Requirements

NPR 7150.2, NASA Software Engineering Requirements

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