



CCSDS

The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

**XML SPECIFICATION
FOR NAVIGATION
DATA MESSAGES**

RECOMMENDED STANDARD

CCSDS 505.0-B-2

BLUE BOOK

May 2021

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FOREWORD

This document is a technical Recommended Standard for an XML Specification for Navigation Data Messages. This Recommended Standard has been developed via consensus of the Navigation Working Group of the CCSDS Mission Operations and Information Management Services (MOIMS) area. The XML schema set described in this Recommended Standard represents the baseline concept for exchanging navigation data in XML format between Agencies of the CCSDS.

This Recommended Standard establishes a common framework and provides a common basis for the interchange of navigation data in XML format. It allows implementing organizations within each Agency to proceed coherently with the development of compatible derived standards for the flight and ground systems that are within their cognizance. Derived Agency standards may implement only a subset of the optional features allowed by the Recommended Standard and may incorporate features not addressed by this Recommended Standard.

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- Swedish Space Corporation (SSC)/Sweden.
- Swiss Space Office (SSO)/Switzerland.
- United States Geological Survey (USGS)/USA.

DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 505.0-B-1	XML Specification for Navigation Data Messages, Recommended Standard, Issue 1	December 2010	Original issue, superseded
CCSDS 505.0-B-2	XML Specification for Navigation Data Messages, Recommended Standard, Issue 2	May 2021	Current issue: – applies general improvements and eliminates overlaps with other CCSDS navigation documents (note).

NOTES

- 1 Textual changes from the original issue are too numerous to permit meaningful use of change bars.
- 2 Substantive changes in the current issue are enumerated in annex F.

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1 INTRODUCTION

1.1 PURPOSE

This Recommended Standard specifies a format for use in exchanging spacecraft navigation data. Such exchanges are used for distributing navigation-related data between space agencies and other space operators. The Recommended Standard specifies an integrated Extensible Markup Language (XML) schema set that applies to Navigation Data Messages (NDMs) defined in the CCSDS Recommended Standards developed by the CCSDS Navigation Working Group (see references [4]–[8]). This XML schema set is suited to interagency exchanges of any number of NDMs.

1.2 SCOPE AND APPLICABILITY

This Recommended Standard is applicable only to the schema content and layout, and to instantiations of the schema, but not to the *transmission* of any instantiation of the schema. The means of transmission of an XML-formatted NDM between exchange participants is beyond the scope of this document; such arrangements require specification via other arrangements, for example, in an Interface Control Document (ICD). Transmission of an XML-formatted NDM could be based on a future CCSDS real-time data transfer service, a file-based transfer protocol such as the Secure File Transfer Protocol (SFTP), streaming media, email, or services provided via the World Wide Web and XML-compatible Web browsers. The potential for compression/decompression of the message is an aspect of the transmission that is not part of this specification. In general, it is a requirement that the transmission mechanism not place constraints on the technical data content of an NDM.

As noted in the Purpose subsection above, this document applies to the NDMs defined in the CCSDS Recommended Standards developed by the CCSDS Navigation Working Group. Historically, the first few such Recommended Standards contained no XML representation. Given the lack of XML representations in these early Recommended Standards, the first version of this NDM/XML document contained information on how to create instantiations of all the messages documented in the Orbit Data Messages (ODM), Attitude Data Messages (ADM), and Tracking Data Message (TDM). Starting with Conjunction Data Message (CDM) in 2013, the XML representation was directly included in the Recommended Standard. XML representations have been added to other Recommended Standards as they have been produced (the Re-Entry Data Message [RDM] in 2019 and the TDM version 2 in 2020). As the early Navigation Working Group Recommended Standards are being revised, the strategy is to remove the XML formatting discussions of ODM and ADM from this NDM/XML document and migrate them into the revised documents.

The first issue of this document only encompassed schemas and messages in which the XML ‘elementFormDefault="unqualified"’ applied. This version of the Recommended Standard expands the scope to include XML ‘elementFormDefault="qualified"’ schemas that can be included/imported into XML schemas for other CCSDS Recommended Standards that wish to leverage Navigation Working Group data structures.

1.3 RATIONALE

This document responds to a requirement levied by the CCSDS to produce an XML format for NDMs. Rather than revise several different CCSDS Recommended Standards, the relevant XML format information was consolidated in Version 1 of this document. It includes sets of requirements and criteria that the XML schema set has been designed to meet. The rationale behind the design of the schema set is described in annex D in order to assist the application engineer in constructing a suitable message.

1.4 STRUCTURE OF THIS DOCUMENT

Section 1 (this section) provides an introduction, scope, normative references, and the description of the document structure.

Section 2 provides a very brief overview of the individual messages that constitute an NDM (i.e., references [4]–[8]). It also provides a very brief overview of XML, and the justification for an integrated NDM/XML schema set.

Section 3 provides an overview of the basic structure of the NDM/XML schema set. This structure is external to the internal structure provided by the constituent messages.

Section 4 provides detailed discussion of the differences between the XML-formatted messages and the Keyword Value Notation (KVN) text-formatted messages described in references [4]–[8]. Instructions for how to construct instantiations of the various message types are provided.

Annex A discusses information security, Space Assigned Numbers Authority (SANA), and patent considerations.

NOTE – This document does not contain an Implementation Conformance Statement (ICS), which is usually shown in Annex A of Blue Books, because the material in this document simply reflects a reformatting of some older documents from KVN to XML. The constituent documents listed in references [4]–[8] either now contain an ICS or will contain an ICS annex upon publication of updated versions now in progress.

Annex B provides instructions on where to find the schema set referenced in this Recommended Standard on the CCSDS Web site. Also provided for illustrative purposes are a number of example instantiations of NDM/XML messages.

Annex C contains a list of informative references.

Annex D lists a set of requirements that were taken into consideration in the design of the NDM/XML schema.

Annex E is a list of abbreviations and acronyms applicable to the NDM/XML.

Annex F describes the changes in this version of the Recommended Standard compared to the previous version.

1.5 CONVENTIONS AND DEFINITIONS

1.5.1 NOMENCLATURE

The following conventions apply throughout this Recommended Standard:

- a) the words ‘shall’ and ‘must’ imply a binding and verifiable specification;
- b) the word ‘should’ implies an optional, but desirable, specification;
- c) the word ‘may’ implies an optional specification;
- d) the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

1.5.2 TERMS

For the purposes of this document, the following definitions apply:

CamelCase: a style of capitalization in which the initial characters of concatenated words are capitalized.

lowerCamelCase: a variant on CamelCase in which the first character of a character string formed from concatenated words is lowercase. In the case of a character string consisting of only a single word, only lowercase characters are used.

ASCII: a text character set defined in reference [C4].

1.6 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommended Standard. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommended Standard are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommended Standards.

- [1] Henry S. Thompson, et al., eds. “XML Schema Part 1: Structures.” W3C Recommendation. 2nd ed., 28 October 2004. The World Wide Web Consortium (W3C). <http://www.w3.org/TR/2004/REC-xmlschema-1-20041028/>.
- [2] Paul V. Biron and Ashok Malhotra, eds. “Extensible Markup Language (XML) 1.0.” W3C Recommendation. 3rd ed., February 2004. <http://www.w3.org/TR/2004/REC-xmlschema-2-20041028/>.

- [3] “Navigation Data Messages XML Schema.” Space Assigned Numbers Authority. <https://sanaregistry.org/r/ndmxml>.
- [4] *Attitude Data Messages*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 504.0-B-1. Washington, D.C.: CCSDS, May 2008.
- [5] *Orbit Data Messages*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 502.0-B-2. Washington, D.C.: CCSDS, November 2009.
- [6] *Tracking Data Message*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 503.0-B-2. Washington, D.C.: CCSDS, June 2020.
- [7] *Conjunction Data Message*. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 508.0-B-1. Washington, D.C.: CCSDS, June 2013.
- [8] *Re-entry Data Message*. Issue 1. Recommendation for (Blue Book), CCSDS 508.1-B-1. Washington, D.C.: CCSDS, November 2019.

NOTE – Informative references are provided in annex C.

2 OVERVIEW

2.1 NAVIGATION DATA MESSAGES

2.1.1 GENERAL

This subsection provides a brief overview of the set of NDMs. There are five basic types of NDM that are covered by the schemas described in this document: Attitude Data Messages (reference [4]), Orbit Data Messages (reference [5]), Tracking Data Message (reference [6]), Conjunction Data Message (reference [7]), and Re-entry Data Message (reference [8]). The remainder of this document conveys the structure of the NDMs in an integrated XML schema set.

2.1.2 ATTITUDE DATA MESSAGES

Attitude Data Messages comprise two message types used to convey spacecraft attitude information: the Attitude Parameter Message (APM) and Attitude Ephemeris Message (AEM). The APM consists of an instantaneous attitude state and optional attitude maneuvers. The AEM consists of a history/forecast of the attitude of the object; the history/forecast can be interpolated to obtain the attitude of the spacecraft at times other than those specified in the message. The APM and AEM are specified in reference [4].

2.1.3 ORBIT DATA MESSAGES

Orbit Data Messages comprise three message types used to convey trajectory information: the Orbit Parameter Message (OPM), Orbit Mean Elements Message (OMM), and Orbit Ephemeris Message (OEM). The OPM consists of a single state vector at a given time that can be propagated to generate the trajectory of the spacecraft; specifications of maneuvers are optional. Like the OPM, the OMM also represents an orbit state, but it is calculated on the basis of mean orbital elements instead of osculating elements (there are other differences as well). The OEM represents a history/forecast of state vectors that can be interpolated to obtain the state of the spacecraft at times other than those explicitly specified in the message. The OPM, OMM, and OEM are specified in reference [5].

2.1.4 TRACKING DATA MESSAGE

The Tracking Data Message is a single message type for use in exchanging spacecraft tracking data between space agencies. Such exchanges are used for distributing tracking data output from interagency cross supports in which spacecraft missions managed by one agency are tracked from a ground station managed by a second agency. Additionally, the ability to transfer tracking data between space agencies facilitates the allocation of tracking sessions to alternate antenna resources and increases the ability of space agencies to tolerate availability issues with their primary antennas. The TDM supports commonly used ground-based radiometric data types, spacecraft-to-spacecraft Doppler and range, and ancillary information needed to calculate the measurement residuals. Instructions for creating an instantiation of the TDM version 2 are contained in the TDM document itself. The TDM is specified in reference [6].

2.1.5 CONJUNCTION DATA MESSAGE

The Conjunction Data Message specifies a single message type for use in exchanging spacecraft conjunction information between originators of conjunction assessments and satellite owner/operators and other authorized parties. Such exchanges provide critical information to satellite owner/operators to enable timely collision-avoidance decisions. The CDM is applicable to satellite operations in all environments in which close approaches and collisions among satellites are concerns. Instructions for creating an instantiation of the CDM are contained in the CDM document itself. The CDM is specified in reference [7].

2.1.6 RE-ENTRY DATA MESSAGE

The Re-entry Data Message specifies a single message type for use in exchanging spacecraft re-entry information between space situational-awareness data providers and recipients such as satellite operators, civil protection authorities, and/or aviation authorities. The RDM contains information about a single re-entry event, including identification of the re-entering object; basic re-entry information such as remaining orbital lifetime; whether the re-entry is controlled or not, and which celestial body the object is orbiting; and more complex re-entry information such as re-entry and impact windows, impact location and probabilities, state vector, object properties, the orbit determination process, and observations used to predict the re-entry. The information is used by recipients to assess the re-entry risk and plan any needed mitigation measures. The RDM is not limited to man-made objects re-entering the Earth's atmosphere. It could be used for any entry/impact event by specifying the appropriate center name, reference frame, and object type. Instructions for creating an instantiation of the RDM are contained in the RDM document itself. The RDM is specified in reference [8].

2.2 EXTENSIBLE MARKUP LANGUAGE

2.2.1 GENERAL

This subsection describes very briefly the XML, generalities of the XML Schema Definition (XSD), and the justification for using XML for NDMs. XML schema structures and data types are specified in references [1] and [2].

2.2.2 XML OVERVIEW

2.2.2.1 During the development of the first version of the ODM in the late 1990s/early 2000s, it was determined that the specified KVN format was limited and that it was not necessarily well suited to cover all possible needs of the NDMs. XML can be a much better form of specifying ASCII-based data. XML can also convey binary data using one of its possible ASCII representations (e.g., base-64). This subsection presents a brief description of the broad features of XML.

2.2.2.2 XML is similar to the HyperText Markup Language (HTML) used for creating Web pages, in that there are document tags (begin tags and end tags) that specify how to organize the content. However, HTML has a fixed set of valid tags, while XML provides an extensible framework that allows user-defined tag names that are structured according to the logic of the particular application domain in which the document content exists. Additionally, XML documents are required to be ‘well-formed’, whereas this restriction does not exist for HTML documents. Discussion of the details of ‘well-formedness’ is beyond the scope of this document, but it is essentially a set of rules that describe what constitutes a proper XML document. If the rules are not followed, the document cannot be rendered correctly. HTML is less strict.

2.2.2.3 Some of the advantages of using XML instead of standard text files for the Navigation Data Messages application include:

- XML allows for the definition of the data message in a format that is readable both by humans and machines. The format is basically defined by a template called an XSD, or simply ‘schema’. This schema can then be referred to in the XML document, and it can be used to verify that the data structure and content are compliant with the schema. There are widely available programs to specify a schema, to assist with the processing of XML data, and to automatically verify that the data messages comply with the schema. Each participant in a data exchange can independently verify that the message is compliant. This can simplify the development and validation of the software used to write data in the proper format.
- XML defines standards for time formats and numerical values against which it is possible to validate the contents of an XML element.
- XML allows for the nesting of data so it is clear which metadata corresponds to which data.
- XML allows for the specification of default and alternative attributes, such as units.
- XML allows for required and optional elements and attributes.
- XML allows for range checking and specification of lists of allowed values.
- XML allows for sharing elements between different specifications.

2.2.2.4 A few disadvantages of using XML for this application are:

- Tags are always duplicated, with the opening tag and the corresponding ending tag making files bigger (in some cases, it is possible that the byte count for tag information exceeds the byte count of the actual data associated with the tags). However, there are specific compressors for XML data (e.g., XMILL and XGRIND—references [C5] and [C6]) that are much more efficient than those used for non-XML-formatted ASCII data.
- Some values can be specified as either attributes or child elements, so there could be disagreement as to which method to use. This flexibility can also be seen as an advantage, depending upon the application and the implementation.
- There are not many Flight Dynamics specialists who are skilled in XML.
- There is not much Flight Dynamics software that can deal with data in XML format.

2.2.3 JUSTIFICATION FOR USING XML SCHEMA

There are several ways in which XML files can be processed, for example: without validation, with validation via Document Type Definition (DTD), with validation via RELAX NG (reference [C7]), with validation via Schematron (reference [C8]), and with validation via XML schema (references [1] and [2]). In the case of the CCSDS, the CCSDS Management Council (CMC) has specified that the XML Schema method be used for XML validation.¹ The Navigation Working Group has therefore developed XML schema implementations for its Recommended Standards, consistent with the directive of the CMC. These schema representations adopt the standard as approved by the World Wide Web Consortium (W3C) (<https://www.w3.org/>).

2.2.4 JUSTIFICATION FOR INTEGRATED NDM/XML SCHEMA SET

There has been a movement towards the adoption of XML for space data systems data interchange between agencies (e.g., the XML Telemetry and Command Exchange (XTCE) developed by the Space Domain Task Force of the Object Management Group). Since there are a number of separate NDM message types, some of which have considerable overlap in structure and/or content, it is more efficient to structure the XML format for the set of NDMs into an integrated set. This will help to ensure as much consistency and re-use as possible between the message implementations and facilitates the coding of programs that will produce the messages that will be exchanged.

The integrated NDM/XML schema set is stored in the CCSDS SANA repository, accessible by all interested parties. Via such an arrangement, agencies creating instantiations of an NDM/XML schema will be able to download the schema set from the CCSDS site to an operations server in their own agencies. This will allow agencies to control the reliability and operations aspects of providing the XML message types and will ensure that all instantiations of an NDM/XML schema can be validated in a consistent manner. Periodic updates of elements of the schema set could be necessary in order to retain the correspondence to the KVN-formatted messages or to correct errors in an individual schema, at which time agencies would download new copies of the schema set. An agency that downloads a copy of the NDM/XML schema set to an operations server under its management also has the option of introducing local modifications to the schema set, though doing so could diminish its utility as an interagency exchange medium.

2.3 SPECIAL CONSIDERATIONS

2.3.1 COMMENTS IN NDM/XML INSTANTIATIONS

Each of the KVN format NDMs provides a 'COMMENT' keyword that is used for a variety of documentation purposes. In most cases the individual messages are consistent with

¹ CCSDS Management Council Resolution MC-F02-09 directed Subpanel P1J (precursor to Navigation Working Group) to utilize PVL, or preferably XML schema language, in the CCSDS 502.0-R-2 Orbit Data Messages.

respect to the use of comments, and the placement is the same in the KVN and XML versions. However, for historical reasons, in the original issue of the ODM Recommendation, the allowed placement of comments was much freer than in subsequent Recommendations of the Navigation Working Group. Allowing complete freedom in the placement of comments in a KVN document is not problematic; however, an XML schema supporting such free placement of comments has some difficulties. For example, it could become impossible to convert between the XML and text versions of a message in a way that comments can be uniquely associated to the proper data elements. Allowing comments anywhere also makes a schema overly complex, lengthy, and error prone; obscures the meaningful structure of the schema; and in some cases, makes it impossible for it to be correctly interpreted by XML validators. For these reasons, the CCSDS Navigation Working Group has restricted the placement of comments in all its subsequent standards.

2.3.2 DISCUSSION OF ‘VALIDATION CHECKING’

There are some elements in the NDM Recommended Standards that have structure for which checking could be performed, but is not done in the NDM XML schema set. Specifically, time systems, object names, reference frames, and center names could be defined by an enumerated list, and object IDs could be defined via a matching pattern. However, it has been decided not to enforce these potential restrictions and to allow a generic string to be used for the values associated with these concepts. In future versions of the NDM Recommended Standards, there could be some validation checking imposed based on the requirement to include ‘normative references’ that specifically enumerate the acceptable values for some metadata keywords.

Because of this validation checking convention, the user of one of the messages will be responsible for more validation code at the application level than would be necessary if strict checking and validation were performed at the schema level (for example, if `<TIME_SYSTEM>UVC</TIME_SYSTEM>` is coded, then user code will need to determine that ‘UVC’ is not a valid value for the time system).

The design of the NDM/XML schema set is such that extension to cope with more restrictive validation scenarios is easy to implement:

- restriction on generic values coded as character strings via pattern definition;
- value selection from an enumerated sequence;
- numerical ranges.

3 BASIC STRUCTURE OF THE NDM/XML SCHEMA SET

3.1 NAVIGATION DATA MESSAGES AND THE ASSOCIATED SCHEMA SET

3.1.1 The basic element in the NDM/XML is an NDM. An NDM shall consist of at least one of the messages documented in references [4]–[8].

3.1.2 The NDM/XML schema set shall consist of a schema for the most current Blue Book version² of each individual message type (see references [4]–[8]), an ‘NDM combined instantiation’ schema (see 4.14), a namespace schema, a master validator schema, and a schema containing elements common to more than one Navigation Working Group (see table 3-1).

3.1.3 The NDM/XML schema set shall be available on a CCSDS resource that is internet accessible.

NOTE – The NDM/XML schema set is currently available at:

- <https://sanaregistry.org/r/ndmxml> for links to the two schema subsets below:
 - [https://sanaregistry.org/r/ndmxml_unqualified/\[schemaName\]](https://sanaregistry.org/r/ndmxml_unqualified/[schemaName]) for schemas with the attribute ‘elementFormDefault="unqualified"’;
 - [https://sanaregistry.org/r/ndmxml_qualified/\[schemaName\]](https://sanaregistry.org/r/ndmxml_qualified/[schemaName]) for schemas with the attribute ‘elementFormDefault="qualified"’.

3.1.4 For schemas directly associated with one of the NDM message types, the components of [schemaName] shall be

ndmxml-[ndmxmlVersionNumber]-[messageType]-[blueBookNumber].xsd

where

- [ndmxmlVersionNumber] is formed via the string M.m.X, where ‘M’ is the Blue Book number of this document (i.e., the NDM/XML standard), ‘m’ is a minor revision number of the NDM/XML Blue Book (usually ‘0’), and ‘X’ is a schema revision indicator (‘0’ for the initial version, then {‘A’, ‘B’, ‘C’,...} for successive revisions);
- [messageType] is one of the individual message types described in references [4]–[8] (e.g., OPM, OMM, OEM);
- [blueBookNumber] is the most current Blue Book version corresponding to the message (e.g., ‘1.0’ for the AEM and APM).

² In this document, ‘Blue Book version’ is synonymous with ‘Blue Book issue’.

NOTES

- 1 There are several test files and example NDM/XML instantiations on the CCSDS Navigation Working Group Collaborative Work Environment (CWE) Web site <https://cwe.ccsds.org/moims/docs/MOIMS-NAV/Test-Messages/XML>.
- 2 The following table illustrates the naming convention in the names of the NDM/XML schema set. The ‘Blue Book Supported’ column indicates the message and respective Blue Book to which the schema applies; an asterisk next to the schema name indicates that instructions for creating an instantiation are incorporated in that Blue Book.
- 3 The naming convention for the auxiliary schemas not directly associated with an NDM (common, master, namespace) is similar to the convention for the message-related schemas, but not identical.
- 4 As noted above, each schema is available with ‘elementFormDefault="qualified"’ and ‘elementFormDefault="unqualified"’.

Table 3-1: The NDM/XML Schema Set

Schema	Blue Book Supported	Root Tag
ndmxml-2.0.x-aem-1.0.xsd	ADM Attitude Ephemeris Message (reference [4])	<aem>
ndmxml-2.0.x-apm-1.0.xsd	ADM Attitude Parameter Message (reference [4])	<apm>
ndmxml-2.0.x-cdm-1.0.xsd *	CDM Conjunction Data Message (reference [7])	<cdm>
ndmxml-2.0.x-common-2.n.xsd	Constructs used in more than one NDM schema (‘n’ is a sequence number 0, 1, 2, ...). Supports all references listed in references [4]–[8].	N/A
ndmxml-2.0.x-master-2.n.xsd	NDM/XML master schema, used to validate all instantiations, import NDM/XML namespace, and declare all schema set root elements. Supports all references listed in references [4]–[8].	N/A
ndmxml-2.0.x-namespace-2.n.xsd	Includes each element of the NDM/XML schema set. Supports all references listed in references [4]–[8].	N/A
ndmxml-2.0.x-ndm-2.0.xsd	NDM combined instantiation schema (see 4.14)	<ndm>
ndmxml-2.0.x-oem-2.0.xsd	ODM Orbit Ephemeris Message (reference [5])	<oem>
ndmxml-2.0.x-omm-2.0.xsd	ODM Orbit Mean Elements Message (reference [5])	<omm>
ndmxml-2.0.x-opm-2.0.xsd	ODM Orbit Parameter Message (reference [5])	<opm>
ndmxml-2.0.x-rdm-1.0.xsd *	RDM Re-entry Data Message (reference [8])	<rdm>
ndmxml-2.0.x-tdm-2.0.xsd *	TDM Tracking Data Message (reference [6])	<tdm>

3.2 NDM/XML BASIC STRUCTURE

3.2.1 Each constituent NDM (see messages specified in references [4]–[8]) shall consist of a `<header>` and a `<body>`.

3.2.2 The NDM body shall consist of one or more `<segment>` constructs, depending upon the message type.

3.2.3 Each `<segment>` shall consist of a `<metadata>/<data>` pair.

NOTE – The `<body>` and `<segment>` constructs are not explicitly specified in some of the constituent message documents (see references [4], [5], [6]); however, they are logically implied, and are necessary in order to enforce the strict ordering of metadata and data sections (see section 4).

3.3 SUBSTRUCTURE 1: APM, OMM, OPM, RDM

The body of NDMs that describe a single state (e.g., APM, OMM, OPM, and RDM) shall consist of a single segment, as shown in figure 3-1.

NOTE – In Substructure 1 the `<segment>` tag is not structurally necessary; however, it is present for symmetry with Substructure 2 in the ‘body’ of the message, enabling re-use of some schema data types.

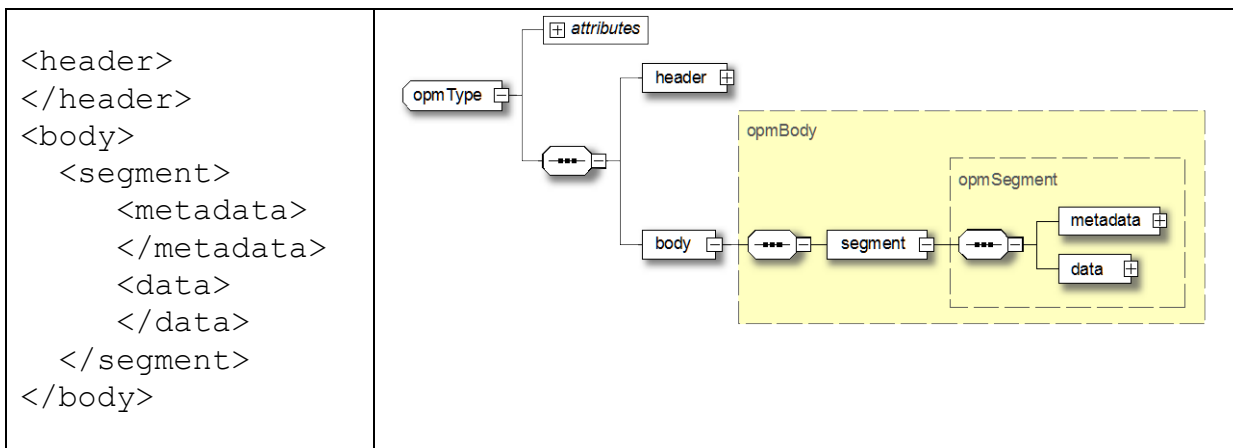


Figure 3-1: NDM/XML Substructure 1 (Single Segment)

3.4 SUBSTRUCTURE 2: AEM, OEM, TDM

3.4.1 The body of NDMs used for messages that describe multiple states or tracking data types (e.g., AEM, OEM, and TDM) shall consist of one or more segments, as shown in figure 3-2.

3.4.2 In substructure 2, at least one segment is required.

NOTES

- 1 The alternation of associated metadata and data sections is the structural element that necessitates the notion of the segment.
- 2 The CDM is a variant of Substructure 2. It contains exactly two segments, and includes a unique ‘Relative Metadata Section’ prior to the first segment (see figure 3-3).

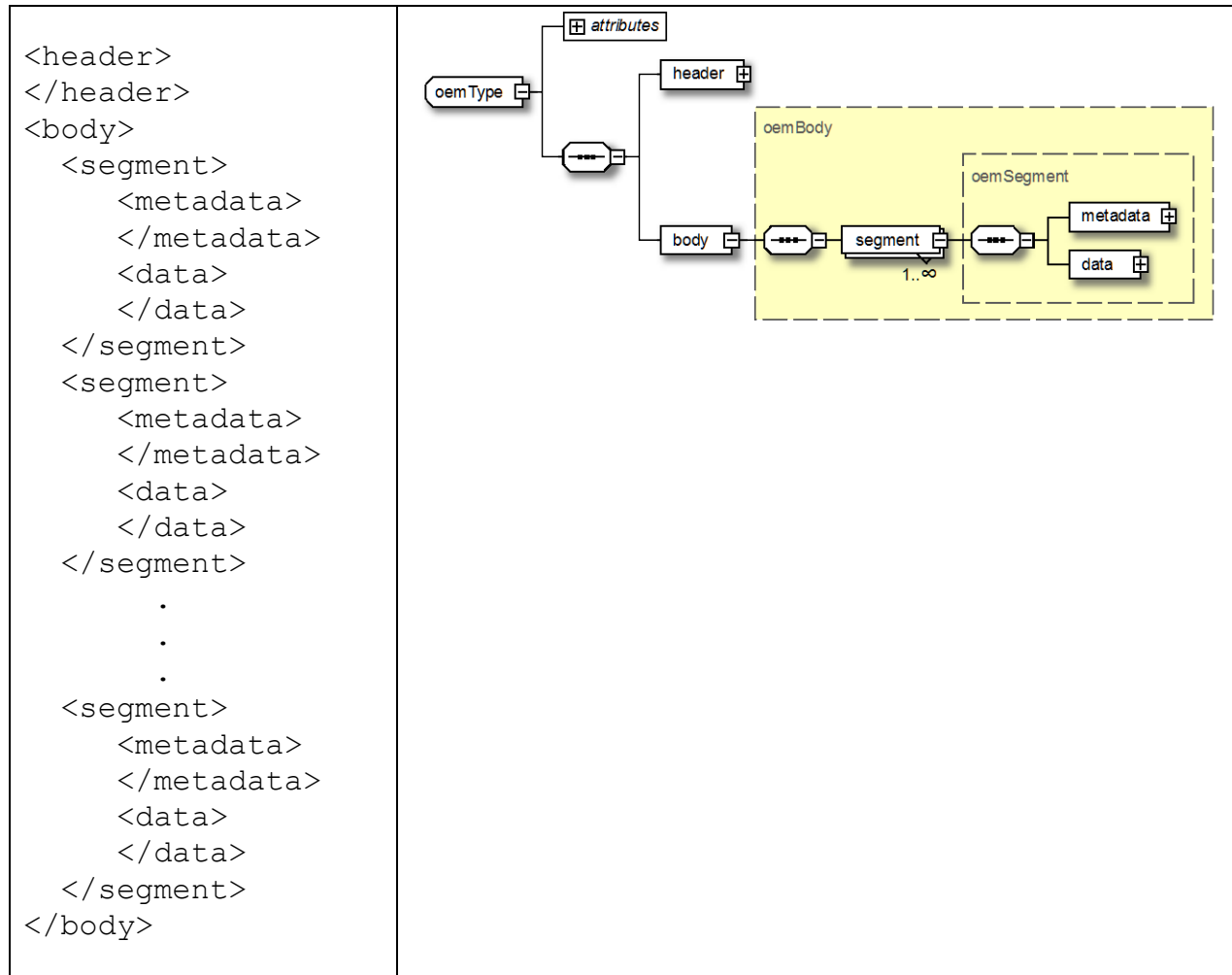


Figure 3-2: NDM/XML Substructure 2 (Possible Multiplicity of Segments)

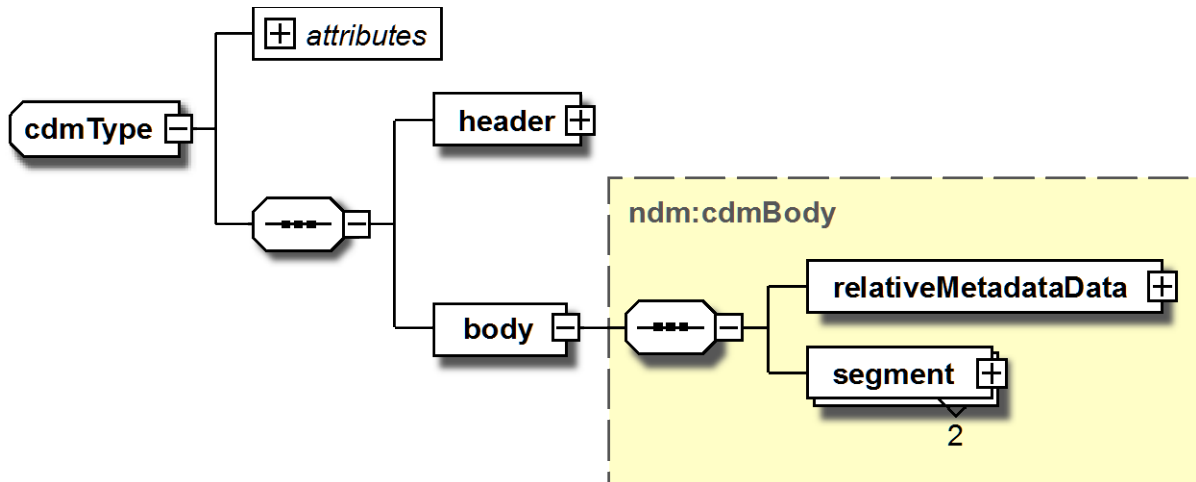


Figure 3-3: Variant of Substructure 2 for CDM

3.5 NDM/XML TAGS

3.5.1 Within the structure and substructures described in 3.2 through 3.4, the individual NDM/XML tags specific to the various message types shall be defined.

3.5.2 NDM/XML tag names shall be identical to the keywords in the reference documents for the KVN representation, with exceptions as noted below and in section 4.

NOTES

- 1 There are three exceptions in which there is not a strict correspondence between KVN keywords in a reference document and NDM/XML tags:
 - a) the 'CCSDS_XXX_VERS' keyword that is present in each document;
 - b) keywords associated with rotations in the ADM (see 4.8.2); and
 - c) keywords associated with user-defined parameters in the ODM (see 4.13).
- 2 In the first two exceptions, the KVN keywords appear as XML attributes rather than as XML elements. In the last case, the KVN keywords appear as a combination of XML elements and attributes. The details of these special cases are described in section 4 of this document, which contains instructions for coding instantiations of the specific messages.

3.5.3 An NDM/XML tag shall be all uppercase if it corresponds directly to a KVN keyword in one of the reference documents.

3.5.4 References [4]–[8] shall define the contents of the specific KVN keyword related NDM/XML tags.

3.5.5 NDM/XML keywords that do not correspond directly to a KVN keyword in one of the special reference documents (references [4]–[8]) shall be in ‘lowerCamelCase’.

3.6 NDM/XML TEXT VALUES

3.6.1 Text values in NDM/XML instantiations (i.e., the values between the element begin and end tags and the values between opening and closing quotes for XML attributes) shall consist of either all uppercase or all lowercase characters, with exceptions as noted in 3.6.2.

NOTE – In some of the KVN format NDMs, it is stated that constructing text values using mixed case is permitted, and that case is not significant. However, this complicates checking for valid values in an XML schema. For example, if the word ‘cat’ is expected for a text value, but case is not significant, then the schema necessarily will allow the values ‘cat’, ‘Cat’, ‘cAt’, ‘caT’, ‘CAt’, ‘CaT’, ‘cAT’, and ‘CAT’. This is a 2ⁿ problem that is not feasible in schema coding for enumerations longer than a few characters. Thus in the NDM/XML schema set, regardless of whether or not mixed case is allowed in the underlying KVN standard, the requirement associated with this note is established.

3.6.2 An exception is made for values between the <COMMENT> and </COMMENT> tags, which may be in any case desired by the user.

4 CONSTRUCTING AN NDM/XML INSTANCE

4.1 OVERVIEW

This section provides more detailed instructions for the user on how to create an XML message based on one of the ASCII-text KVN-formatted messages described in references [4]–[8].

4.2 XML VERSION

The first line of each instantiation shall specify the XML version, exactly as follows:

```
<?xml version="1.0" encoding="UTF-8"?>
```

4.3 BEGINNING THE INSTANTIATION: ROOT ELEMENT TAG

4.3.1 Each instantiation shall have a ‘root element tag’ that identifies the message type and other information specific to the NDM/XML.

NOTE – ‘Other information’ includes things such as where to find the applicable schema, required attributes, etc.

4.3.2 The root element tag in an NDM/XML instantiation shall be one of those listed in the ‘Root Tag’ column of table 3-1.

4.3.3 The XML Schema Instance namespace attribute must appear in the root element tag of all NDM/XML instantiations, exactly as shown:

```
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
```

4.3.4 The NDM/XML namespace must next be coded, exactly as shown:

```
xmlns:ndm="urn:ccsds:schema:ndmxml"
```

4.3.5 The value that follows the ‘xmlns:’ in the NDM/XML name space (‘ndm’ in this case) is a prefix that must be used on every XML tag if it is desired to create an instantiation in an environment that requires ‘elementFormDefault="qualified"’.

NOTE – The NDM/XML schemas for ‘elementFormDefault="qualified"’ and ‘elementFormDefault="unqualified"’ are identical with the exception of the value for the elementFormDefault parameter.

4.3.6 If it is desired to validate an instantiation against the CCSDS Web-based schema, one of the options for the `xsi:noNamespaceSchemaLocation` attribute must be coded as a single string of non-blank characters, with no line breaks:

```
xsi:noNamespaceSchemaLocation="https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-2.0.X-master-2.0.xsd" (if 'elementFormDefault="unqualified"' is desired)
```

```
xsi:noNamespaceSchemaLocation="https://sanaregistry.org/r/ndmxml_qualified/ndmxml-2.0.X-master-2.0.xsd" (if 'elementFormDefault="qualified"' is desired)
```

NOTES

- 1 The value associated with the `xsi:noNamespaceSchemaLocation` attribute shown in this document is too long to appear on a single line.
- 2 In the schema name, the 'X' in '2.0.X' is the most current revision of the NDM/XML schema set, which can be determined via the SANA Registry. For the initial schema set, X = 0 (i.e., 2.0.0 is the initial schema set).

4.3.7 For use in a local operations environment, the NDM/XML schema set may be downloaded from the CCSDS Web site to a local server that meets local requirements for operations robustness.

4.3.8 If a local version is used, the value associated with the `xsi:noNamespaceSchemaLocation` attribute must be changed to a URL that is accessible to the local server.

4.3.9 There are two attributes that are required in the root element tag of an NDM/XML single message instantiation, specifically, the `CCSDS_XXX_VERS` keyword that is also part of the standard KVN header and the Blue Book version number.

4.3.10 The `CCSDS_XXX_VERS` keyword shall be supplied via the 'id' attribute of the root element tag as noted in table 3-1. The value 'xxx' in the 'id' attribute must be in all capital letters.

4.3.11 The version number of the Blue Book to which the schema applies shall be supplied via the 'version' attribute.

NOTE – The following example root element tag for an OPM instantiation combines all the directions in the preceding several subsections for both 'unqualified' and 'qualified' `elementFormDefault`:

```
<?xml version="1.0" encoding="UTF-8"?>
<opm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xmlns:ndm="urn:ccsds:schema:ndmxml"
      xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_unqualified/ndmxml-2.0.0-master-2.0.xsd"
      id="CCSDS_OPM_VERS" version="2.0">
```

```

<?xml version="1.0" encoding="UTF-8"?>
<ndm:opm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:ndm="urn:ccsds:schema:ndmxml"
  xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_qualified/ndmxml-
  2.0.0-master-2.0.xsd"
  id="CCSDS_OPM_VERS" version="2.0">

```

4.4 THE STANDARD NDM/XML HEADER SECTION

4.4.1 The NDMs shall share a standard header format, with tags `<header>` and `</header>`.

4.4.2 Immediately following the `<header>` tag, the message may have any number of `<COMMENT></COMMENT>` tag pairs.

4.4.3 The standard NDM header shall contain the `<CREATION_DATE>` and the `<ORIGINATOR>` tags.

NOTE – The rules for these keywords are specified in references [4]–[8]. An example `<header>` section is shown immediately below for both ‘unqualified’ and ‘qualified’ elementFormDefault. In some of the recent publications, an optional ‘MESSAGE_ID’ keyword has been included in the message header; details are in the specific reference.

```

<header>
  <COMMENT>This is the common NDM/XML header</COMMENT>
  <COMMENT>I can put as many comments here as I want,</COMMENT>
  <COMMENT>including none.</COMMENT>
  <CREATION_DATE>2004-281T17:26:06</CREATION_DATE>
  <ORIGINATOR>AGENCY-X</ORIGINATOR>
</header>

<ndm:header>
  <ndm:COMMENT>This is the common NDM/XML header</ndm:COMMENT>
  <ndm:COMMENT>I can put as many comments here as I want,</ndm:COMMENT>
  <ndm:COMMENT>including none.</ndm:COMMENT>
  <ndm:CREATION_DATE>2004-281T17:26:06</ndm:CREATION_DATE>
  <ndm:ORIGINATOR>AGENCY-X</ndm:ORIGINATOR>
</ndm:header>

```

4.5 THE NDM BODY SECTION

4.5.1 After coding the `<header>`, the instantiation must include a `<body></body>` tag pair.

4.5.2 Inside the `<body></body>` tag pair must appear at least one `<segment></segment>` tag pair.

4.5.3 Each segment must be made up of one or more `<metadata></metadata>` and `<data></data>` tag pairs.

4.6 THE NDM METADATA SECTION

4.6.1 All NDMs must have a metadata section.

4.6.2 The metadata section shall be set off by the `<metadata></metadata>` tag combination.

4.6.3 Between the `<metadata>` and `</metadata>` tags, the keywords shall be the same as those in the metadata sections in references [4]–[8], with exceptions as noted in the following subsections that discuss creating instantiations of the specific messages.

4.7 THE NDM DATA SECTION

4.7.1 All NDMs must have a data section.

4.7.2 The data section shall follow the metadata section and shall be set off the by the `<data></data>` tag combination.

4.7.3 Between the `<data>` and `</data>` tags, the keywords shall be the same as those in the data sections in the references [4]–[8], with exceptions as noted in the following subsections that discuss creating instantiations of the specific messages.

4.8 CREATING AN AEM INSTANTIATION

4.8.1 GENERAL

4.8.1.1 An AEM instantiation shall be delimited with the `<aem></aem>` root element tags using the standard attributes documented in 4.3.

NOTE – Figures B-1 and B-2 in annex B provide example AEM instantiations.

4.8.1.2 The final attributes of the `<aem>` tag shall be ‘id’ and ‘version’.

4.8.1.3 The ‘id’ attribute shall be ‘id="CCSDS_AEM_VERS"’.

4.8.1.4 The ‘version’ attribute for the version of the AEM described in reference [4] shall be ‘version="1.0"’.

4.8.1.5 The standard NDM header shall follow the `<aem>` tag (see 4.3.4).

4.8.1.6 The AEM `<body>` shall consist of one or more `<segment>` constructs (see figure 3-2).

4.8.1.7 Each `<segment>` shall consist of a `<metadata>` section and a `<data>` section.

4.8.1.8 The keywords in the <metadata> and <data> sections shall be those specified in reference [4].

NOTE – The rules for including any of the keyword tags in the instantiation are the same as those specified for the AEM in reference [4].

4.8.1.9 Tags for keywords specified in reference [4] shall be all uppercase as in reference [4].

4.8.2 SPECIAL TAGS IN THE AEM BODY

NOTE – In addition to the AEM keywords specified in reference [4], there are several special tags associated with the AEM body as described in the next few subsections.

4.8.2.1 The <attitudeState> tag shall be used to encapsulate the keywords associated with the structure of one of the attitude ephemeris data line types.

4.8.2.2 The NDM/XML tags used within the <attitudeState> structure shall be drawn from table 4-1.

Table 4-1: Special Tags Used in the AEM Body

AEM 'ATTITUDE_TYPE' Metadata Value	Associated NDM/XML Tag in the <attitudeState>
QUATERNION	<quaternionState>
QUATERNION/DERIVATIVE	<quaternionDerivative>
QUATERNION/RATE	<quaternionEulerRate>
EULER_ANGLE	<eulerAngle>
EULER_ANGLE/RATE	<eulerAngleRate>
SPIN	<spin>
SPIN/NUTATION	<spinNutation>

4.8.2.3 Between the begin tag and end tag (e.g., between <quaternionState> and </quaternionState>), the user shall place the values required by the specific ephemeris data line type as specified in reference [4].

4.8.2.4 In the XML representation of the AEM, the components of the <attitudeState> ephemeris data line must be represented with keywords (i.e., a tag).

4.8.2.5 The <attitudeState> keywords shall be the same as those defined for the same construct in the APM.

NOTE – In the KVN representations of the ephemeris data lines, keywords are not used. Rather, the components of the ephemeris data line appear in an order defined by the specific ephemeris data line type.

4.8.2.6 The `<rotation*>` constructs shall be used to encapsulate the keywords associated with the structure of one of the rotation sequences.

NOTE – Some `<attitudeState>` entries include angles only, or rates only, or both angles and rates.

4.8.2.7 The NDM/XML tags used within the `<rotation*>` structure shall be drawn from table 4-2.

Table 4-2: AEM Rotation Tags

<code><attitudeState></code> Tag	Associated Rotation Tag in the <code><attitudeState></code>
<code><quaternionEulerRate></code>	<code><rotationRates></code>
<code><eulerAngle></code>	<code><rotationAngles></code>
<code><eulerAngleRate></code>	<code><rotationAngles></code> followed immediately by <code><rotationRates></code> .

4.8.2.8 The `<rotationAngles>` and `<rotationRates>` elements shall be composed of three tags: `<rotation1>`, `<rotation2>`, and `<rotation3>`.

NOTE – Depending on whether angles or rates are being described, these `<rotationi>` ($i=1,2,3$) keywords have different attributes.

4.8.2.9 For `<rotationi>` tags in the `<rotationAngles>` element, the attributes shall be ‘angle=’ and ‘units="deg"’.

4.8.2.10 The ‘angle’ attribute must be coded on the `<rotationi>` tag.

4.8.2.11 The ‘units’ attribute may be coded on the `<rotationi>` tag.

4.8.2.12 The value associated with the ‘angle’ attribute must be chosen from the values ‘X_ANGLE’, ‘Y_ANGLE’, ‘Z_ANGLE’.

NOTE – ‘X_ANGLE’, ‘Y_ANGLE’, and ‘Z_ANGLE’ are keywords from the KVN AEM.

4.8.2.13 For `<rotationi>` tags in the `<rotationRates>` element, the attributes shall be ‘rate=’ and ‘units="deg/s"’.

4.8.2.14 The ‘rate’ attribute must be coded on the `<rotationi>` tag.

4.8.2.15 The ‘units’ attribute may be coded on the `<rotationi>` tag.

4.8.2.16 The value associated with the ‘rate’ attribute must be chosen from the values ‘X_RATE’, ‘Y_RATE’, ‘Z_RATE’.

NOTE – ‘X_RATE’, ‘Y_RATE’, and ‘Z_RATE’ are keywords from the KVN AEM.

4.8.3 DISCUSSION

This non-normative subsection discusses and provides examples of the use of quaternion tags in the AEM.

The XML representations of quaternions in the ADM constituent messages share a common quaternion definition. However, there are some differences in those definitions in the underlying KVN definitions of the APM and AEM. As in the KVN representation of the quaternion, it is possible to code the tags for the individual components of the quaternion (Q1, Q2, Q3, QC) in either of the standard orders (i.e., scalar component first or last). The following examples are meant to illustrate the standard for representing quaternions in the AEM.

Here is an example AEM quaternion for a ‘QUATERNION’ ephemeris data line:

```
<attitudeState>
  <quaternionState>
    <EPOCH>2004-100T00:00:00</EPOCH>
    <quaternion>
      <Q1>0.00005</Q1>
      <Q2>0.87543</Q2>
      <Q3>0.40949</Q3>
      <QC>0.25678</QC>
    </quaternion>
  </quaternionState>
</attitudeState>
```

Here is an example AEM quaternion for a ‘QUATERNION/DERIVATIVE’ ephemeris data line:

```
<attitudeState>
  <quaternionDerivative>
    <EPOCH>2004-100T00:00:00</EPOCH>
    <quaternion>
      <Q1>0.00005</Q1>
      <Q2>0.87543</Q2>
      <Q3>0.40949</Q3>
      <QC>0.25678</QC>
    </quaternion>
    <quaternionRate>
      <Q1_DOT>0.002</Q1_DOT>
      <Q2_DOT>0.003</Q2_DOT>
      <Q3_DOT>0.004</Q3_DOT>
      <QC_DOT>0.001</QC_DOT>
    </quaternionRate>
  </quaternionDerivative>
</attitudeState>
```


Here is an example AEM quaternion for a ‘QUATERNION/RATE’ ephemeris data line:

```

<attitudeState>
  <quaternionEulerRate>
    <EPOCH>2004-100T00:00:00</EPOCH>
    <quaternion>
      <Q1>0.00005</Q1>
      <Q2>0.87543</Q2>
      <Q3>0.40949</Q3>
      <QC>0.25678</QC>
    </quaternion>
    <rotationRates>
      <rotation1 rate="X_RATE">1.0</rotation1>
      <rotation2 rate="Y_RATE">1.1</rotation2>
      <rotation3 rate="X_RATE">1.2</rotation3>
    </rotationRates>
  </quaternionEulerRate>
</attitudeState>

```

4.8.4 DISCUSSION

This non-normative subsection discusses and provides examples of the use of rotation tags in the AEM.

The `<aem>` is notable in that there are XML attributes used to convey the characteristics of rotations instead of XML elements. The AEM includes a number of rotation-related constructs that are necessitated by the fact that attitude rotations are not of one type. The rotation combinations are complicated by the fact that some rotation sequences are specified with more than one rotation about the same axis (e.g., a ‘131’ rotation, in which the first rotation is about the x-axis, second about the z-axis, and the final rotation again about the x-axis). The rotation constructs are used to encapsulate the keywords associated with the structure of one of the rotation sequences. Some `<attitudeState>` entries include angles only, or rates only, or both angles and rates. The `<rotationAngles>` and `<rotationRates>` elements are composed of three tags: `<rotation1>`, `<rotation2>`, and `<rotation3>`. Depending on whether angles or rates are being described, these `<rotation i >` ($i=1,2,3$) keywords have different attributes. For example, the following shows rotation angles for a 321 rotation sequence:

```

<rotationAngles>
  <rotation1 angle="Z_ANGLE">1.234</rotation1>
  <rotation2 angle="Y_ANGLE">5.678</rotation2>
  <rotation3 angle="X_ANGLE">9.1011</rotation3>
</rotationAngles>

```

For example, the following shows rotation rates for a 321 rotation sequence:

```
<rotationRates>
  <rotation1 rate="Z_RATE" units="deg/s">1.234</rotation1>
  <rotation2 rate="Y_RATE" units="deg/s">5.678</rotation2>
  <rotation3 rate="X_RATE" units="deg/s">9.1011</rotation3>
</rotationRates>
```

4.9 CREATING AN APM INSTANTIATION

4.9.1 An APM instantiation shall be delimited by the `<apm></apm>` root element tags using the standard attributes documented in 4.3.

NOTE – Figure B-3 in annex B provides an example APM instantiation.

4.9.2 The final attributes of the `<apm>` tag shall be ‘id’ and ‘version’.

4.9.3 The ‘id’ attribute shall be ‘id="CCSDS_APM_VERS"’.

4.9.4 The ‘version’ attribute for the version of the APM described in reference [4] shall be ‘version="1.0"’.

4.9.5 The standard NDM header shall follow the `<apm>` tag (see 4.3.4).

4.9.6 The APM `<body>` shall consist of a single `<segment>` (see figure 3-1).

4.9.7 The segment shall consist of a `<metadata>` section and a `<data>` section.

4.9.8 The keywords in the `<metadata>` and `<data>` sections shall be those specified in reference [4].

NOTE – The rules for including any of the keyword tags in the instantiation are the same as those specified for the APM in reference [4].

4.9.9 Tags for keywords specified in reference [4] shall be all uppercase as in reference [4].

4.9.10 Several of the NDM/XML APM keywords may have a unit attribute, if desired by the APM producer.

4.9.11 In all cases, the units shall match those defined in reference [4].

4.9.12 Table 4-3 illustrates the keyword tags for which units may be specified:

Table 4-3: APM Tags with Units

Keyword	Units	Example
Q1_DOT	1/s	<Q1_DOT units="1/s">numeric-value</Q1_DOT>
Q2_DOT	1/s	<Q2_DOT units="1/s">numeric-value</Q2_DOT>
Q3_DOT	1/s	<Q3_DOT units="1/s">numeric-value</Q3_DOT>
QC_DOT	1/s	<QC_DOT units="1/s">numeric-value</QC_DOT>
SPIN_ALPHA	deg	<SPIN_ALPHA units="deg">numeric-value</SPIN_ALPHA>
SPIN_DELTA	deg	<SPIN_DELTA units="deg">numeric-value</SPIN_DELTA>
SPIN_ANGLE	deg	<SPIN_ANGLE units="deg">numeric-value</SPIN_ANGLE>
SPIN_ANGLE_VEL	deg/s	<SPIN_ANGLE_VEL units="deg/s">numeric-value</SPIN_ANGLE_VEL>
NUTATION	deg	<NUTATION units="deg">numeric-value</NUTATION>
NUTATION_PER	s	<NUTATION_PER units="s">numeric-value</NUTATION_PER>
NUTATION_PHASE	deg	<NUTATION_PHASE units="deg">numeric-value</NUTATION_PHASE>
I11	kg*m**2	<I11 units="kg*m**2">numeric-value</I11>
I22	kg*m**2	<I22 units="kg*m**2">numeric-value</I22>
I33	kg*m**2	<I33 units="kg*m**2">numeric-value</I33>
I12	kg*m**2	<I12 units="kg*m**2">numeric-value</I12>
I13	kg*m**2	<I13 units="kg*m**2">numeric-value</I13>
I23	kg*m**2	<I23 units="kg*m**2">numeric-value</I23>
MAN_DURATION	s	<MAN_DURATION units="s">numeric-value</MAN_DURATION>
MAN_TOR_1	N*m	<MAN_TOR_1 units="N*m">numeric-value</MAN_TOR_1>
MAN_TOR_2	N*m	<MAN_TOR_2 units="N*m">numeric-value</MAN_TOR_2>
MAN_TOR_3	N*m	<MAN_TOR_3 units="N*m">numeric-value</MAN_TOR_3>

4.9.13 SPECIAL TAGS IN THE APM BODY

NOTE – In addition to the APM keywords specified in reference [4], there are several special tags associated with the APM body as described in the next few subsections. The information content in the APM is separated into constructs described in reference [4] as ‘logical blocks’. Special tags in the APM are used to encapsulate the information in the logical blocks of the APM.

4.9.13.1 The NDM/XML tags used to delimit the logical blocks of the APM shall be drawn from table 4-4.

Table 4-4: Special Tags Used in the APM Body

APM Logical Block	Associated NDM/XML APM Tag
Quaternion	<quaternionState>, <quaternion>, <quaternionRate>
Euler Elements / Three Axis Stabilized	<eulerElementsThree>
Euler Elements / Spin Stabilized	<eulerElementsSpin>
Spacecraft Parameters	<spacecraftParameters>
Maneuver Parameters	<maneuverParameters>

4.9.13.2 Between the begin tag and end tag (e.g., between `<spacecraftParameters>` and `</spacecraftParameters>`), the user shall place the keywords required by the specific logical block as specified in reference [4].

NOTE – The Quaternion logical block has two primary NDM/XML tags associated with it: `<quaternionState>` and `<quaternionRate>`; within the `<quaternionState>` block, there is a `<quaternion>` tag that contains the components of the quaternion itself.

4.9.13.3 The `<rotation*>` constructs shall be used to encapsulate the keywords associated with the structure of one of the rotation sequences.

4.9.13.4 The NDM/XML tags used within the `<rotation*>` structure shall be drawn from table 4-5.

Table 4-5: APM Rotation Tags

APM Tag	Associated Rotation Tag in the <code><eulerElementsThree></code>
<code><eulerElementsThree></code> , after the <code><RATE FRAME></code> tag	<code><rotationAngles></code> <code><rotationRates></code>

4.9.13.5 The `<rotationAngles>` and `<rotationRates>` elements shall be composed of three tags: `<rotation1>`, `<rotation2>`, and `<rotation3>`.

NOTE – Depending on whether angles or rates are being described, these `<rotationi>` ($i=1,2,3$) keywords have different attributes.

4.9.13.6 For `<rotationi>` tags in the `<rotationAngles>` element, the attributes shall be `'angle='` and `'units="deg"`.

4.9.13.7 The `'angle'` attribute must be coded on the `<rotationi>` tag.

4.9.13.8 The `'units'` attribute may be coded on the `<rotationi>` tag.

4.9.13.9 The value associated with the `'angle'` attribute must be chosen from the values `'X_ANGLE'`, `'Y_ANGLE'`, `'Z_ANGLE'`.

NOTE – `'X_ANGLE'`, `'Y_ANGLE'`, and `'Z_ANGLE'` are keywords from the KVN APM.

4.9.13.10 For `<rotationi>` tags in the `<rotationRates>` element, the attributes shall be `'rate='` and `'units="deg/s"`.

4.9.13.11 The `'rate'` attribute must be coded on the `<rotationi>` tag.

4.9.13.12 The ‘units’ attribute may be coded on the <rotation*i*> tag.

4.9.13.13 The value associated with the ‘rate’ attribute must be chosen from the values ‘X_RATE’, ‘Y_RATE’, ‘Z_RATE’.

NOTE – ‘X_RATE’, ‘Y_RATE’, and ‘Z_RATE’ are keywords from the KVN APM.

4.9.14 DISCUSSION

This non-normative subsection discusses and provides examples of the use of quaternion tags in the APM.

The XML representations of quaternions in the ADM constituent messages share a common quaternion definition. However, there are some differences in those definitions in the underlying KVN definitions of the APM and AEM. As in the KVN representation of the quaternion, it is possible to code the tags for the individual components of the quaternion (Q1, Q2, Q3, QC) in either of the standard orders (i.e., scalar component first or last). The following examples are meant to illustrate the standard for representing quaternions in the APM.

Here is an example APM quaternion construct:

```
<quaternionState>
  <EPOCH>2004-100T00:00:00Z</EPOCH>
  <Q_FRAME_A>ICRF</Q_FRAME_A>
  <Q_FRAME_B>ICRF</Q_FRAME_B>
  <Q_DIR>B2A</Q_DIR>
  <quaternion>
    <Q1>0.00005</Q1>
    <Q2>0.87543</Q2>
    <Q3>0.40949</Q3>
    <QC>0.25678</QC>
  </quaternion>
</quaternionState>
```

Here is an example APM quaternion construct with the optional derivative:

```
<quaternionState>
  <EPOCH>2004-100T00:00:00Z</EPOCH>
  <Q_FRAME_A>ICRF</Q_FRAME_A>
  <Q_FRAME_B>ICRF</Q_FRAME_B>
  <Q_DIR>B2A</Q_DIR>
  <quaternion>
    <Q1>0.00005</Q1>
    <Q2>0.87543</Q2>
    <Q3>0.40949</Q3>
    <QC>0.25678</QC>
  </quaternion>
```

```

    <quaternionRate>
      <Q1_DOT>0.002</Q1_DOT>
      <Q2_DOT>0.003</Q2_DOT>
      <Q3_DOT>0.004</Q3_DOT>
      <QC_DOT>0.001</QC_DOT>
    </quaternionRate>
  </quaternionState>

```

4.9.15 DISCUSSION

This non-normative subsection discusses and provides examples of the use of rotation tags in the APM.

The APM includes two rotation-related constructs that are used in conjunction with the `<eulerElementsThree>` tag. The rotation combinations are complicated by the fact that some rotation sequences are specified with more than one rotation about the same axis (e.g., a ‘131’ rotation, in which the first rotation is about the x-axis, second about the z-axis, and the final rotation again about the x-axis). The rotation constructs are used to encapsulate the keywords associated with the structure of one of the rotation sequences. As in the KVN APM, angles can be specified without rates, rates can be specified without angles, or both angles and rates can be specified. The `<rotationAngles>` and `<rotationRates>` elements are composed of three tags: `<rotation1>`, `<rotation2>`, and `<rotation3>`. Depending on whether angles or rates are being described, these `<rotationi>` ($i=1,2,3$) keywords have different attributes.

For example, the following shows rotation angles for a 321 rotation sequence:

```

<rotationAngles>
  <rotation1 angle="Z_ANGLE">1.234</rotation1>
  <rotation2 angle="Y_ANGLE">5.678</rotation2>
  <rotation3 angle="X_ANGLE">9.1011</rotation3>
</rotationAngles>

```

For example, the following shows rotation rates for a 321 rotation sequence:

```

<rotationRates>
  <rotation1 rate="Z_RATE" units="deg/s">1.234</rotation1>
  <rotation2 rate="Y_RATE" units="deg/s">5.678</rotation2>
  <rotation3 rate="X_RATE" units="deg/s">9.1011</rotation3>
</rotationRates>

```

4.10 CREATING AN OEM INSTANTIATION

4.10.1 GENERAL

4.10.1.1 An OEM instantiation shall be delimited with the `<oem></oem>` root element tags using the standard attributes documented in 4.3.

NOTE – Figure B-4 in annex B provides an example OEM instantiation.

4.10.1.2 The final attributes of the `<oem>` tag shall be 'id' and 'version'.

4.10.1.3 The 'id' attribute shall be 'id="CCSDS_OEM_VERS"'.

4.10.1.4 The 'version' attribute for the version of the OEM described in reference [5] shall be 'version="2.0"'.

4.10.1.5 The standard NDM header shall follow the `<oem>` tag (see 4.3.4).

4.10.1.6 The OEM `<body>` shall consist of one or more `<segment>` constructs (see figure 3-2).

4.10.1.7 Each `<segment>` shall consist of a `<metadata>` section and a `<data>` section.

4.10.1.8 The keywords in the `<metadata>` and `<data>` sections shall be those specified in reference [5].

NOTE – The rules for including any of the keyword tags in the instantiation are the same as those specified for the OEM in reference [5].

4.10.1.9 Tags for keywords specified in reference [5] shall be all uppercase as in reference [5].

4.10.2 SPECIAL TAGS IN THE OEM BODY

NOTE – In addition to the OEM keywords specified in reference [5], there are some special tags associated with the OEM body as described in the next subsections.

4.10.2.1 The `<stateVector>` tag shall encapsulate the keywords associated with one of the ephemeris data lines in the OEM.

4.10.2.2 In the XML representation of the OEM, the components of the `<stateVector>` ephemeris data line must be represented with keywords (i.e., a tag).

4.10.2.3 The `<stateVector>` keywords shall be the same as those defined for the same construct in the OPM.

NOTE – In the KVN representations of the ephemeris data lines, keywords are not used. Rather, the components of the ephemeris data line appear in an order defined by reference [5]. Similarly, units are not used in the KVN version of the OEM; however, they are optional in the XML OEM.

4.10.2.4 Since the state vector structure is shared by the OPM schema and OEM schema, units may optionally appear in the XML version of the OEM ephemeris data line.

4.10.2.5 The NDM/XML tags used within the `<stateVector>` structure shall be drawn from table 4-6.

Table 4-6: Special Tags Used in the OEM Body

OEM Tag	Represents	Example
<code><EPOCH></code>	time tag of the state	<code><EPOCH>2007-09-20T17:41:00</EPOCH></code>
<code><X></code>	x component of position	<code><X units="km">6678.0</X></code>
<code><Y></code>	y component of position	<code><Y units="km">0.0</Y></code>
<code><Z></code>	z component of position	<code><Z units="km">0.0</Z></code>
<code><X_DOT></code>	x component of velocity	<code><X_DOT units="km/s">0.0</X_DOT></code>
<code><Y_DOT></code>	y component of velocity	<code><Y_DOT units="km/s">7.73</Y_DOT></code>
<code><Z_DOT></code>	z component of velocity	<code><Z_DOT units="km/s">0.0</Z_DOT></code>
<code><X_DDOT></code>	x component of acceleration	<code><X_DDOT units="km/s**2">0.0</X_DDOT></code>
<code><Y_DDOT></code>	y component of acceleration	<code><Y_DDOT units="km/s**2">0.50</Y_DDOT></code>
<code><Z_DDOT></code>	z component of acceleration	<code><Z_DDOT units="km/s**2">0.0</Z_DDOT></code>

4.10.2.6 Between the begin tag and end tag (i.e., between `<stateVector>` and `</stateVector>`), the user shall place the values required by the ephemeris data line as specified in reference [5].

4.10.2.7 The `<covarianceMatrix>` tag shall encapsulate the keywords associated with the covariance matrix lines in the OEM.

4.10.2.8 In the XML representation of the OEM, the covariance data line must be represented with keywords (i.e., a tag).

4.10.2.9 The OEM `<covarianceMatrix>` keywords shall be the same as those defined for the same construct in the OPM and OMM.

NOTE – In the KVN representations of the OEM covariance matrix data lines, keywords are not used. Rather, the components of the covariance matrix data line appear in an order defined by reference [5]. Similarly, units are not used in the KVN version of the OEM covariance matrix; however, they are optional in the OPM and OMM and thus may be used in the OEM XML covariance matrix.

4.10.2.10 The NDM/XML tags used within the <covarianceMatrix> structure shall be drawn from table 4-7.

Table 4-7: Special Tags Used in the OEM Covariance Matrix

Keyword	Units	Example
CX_X, CY_X, CY_Y, CZ_X, CZ_Y, CZ_Z	km**2	<CX_X units="km**2">numeric-value</CX_X>
CX_DOT_X, CX_DOT_Y, CX_DOT_Z, CY_DOT_X, CY_DOT_Y, CY_DOT_Z, CZ_DOT_X, CZ_DOT_Y, CZ_DOT_Z	km**2/s	<CX_DOT_X units="km**2/s">numeric-value</CX_DOT_X>
CX_DOT_X_DOT, CY_DOT_X_DOT, CY_DOT_Y_DOT, CZ_DOT_X_DOT, CZ_DOT_Y_DOT, CZ_DOT_Z_DOT	km**2/s**2	<CX_DOT_X_DOT units="km**2/s**2">numeric-value</CX_DOT_X_DOT>

4.10.2.11 Between the begin tag and end tag (i.e., between <covarianceMatrix> and </covarianceMatrix>), the user shall place the values required by the covariance matrix line type as specified in reference [5].

4.10.2.12 Since the covariance matrix structure is shared by the OPM, OMM, and OEM, units may optionally appear in the XML version of the OEM covariance matrix line.

4.11 CREATING AN OMM INSTANTIATION

4.11.1 An OMM instantiation shall be delimited with the <omm></omm> root element tags using the standard attributes documented in 4.3.

NOTE – Figure B-5 in annex B provides an example OMM instantiation.

4.11.2 The final attributes of the <omm> tag shall be 'id' and 'version'.

4.11.3 The 'id' attribute shall be 'id="CCSDS_OMM_VERS"'.

4.11.4 The 'version' attribute for the version of the OMM described in reference [5] shall be 'version="2.0"'.

4.11.5 The standard NDM header shall follow the <omm> tag (see 4.3.4).

4.11.6 The OMM <body> shall consist of a single <segment> (see figure 3-1).

4.11.7 The <segment> shall consist of a <metadata> section and a <data> section.

4.11.8 The keywords in the <metadata> and <data> sections shall be those specified in reference [5].

NOTE – The rules for including any of the keyword tags in the instantiation are the same as those specified for the OMM in reference [5].

4.11.9 Tags for keywords specified in reference [5] shall be all uppercase as in reference [5].

4.11.10 Several of the NDM/XML OMM keywords may have a unit attribute, if desired by the OMM producer.

4.11.11 In all cases, the units shall match those defined in reference [5].

4.11.12 Table 4-8 lists the keyword tags for which units may be specified.

Table 4-8: OMM Tags with Units

Keyword	Units	Example
SEMI_MAJOR_AXIS	km	<SEMI_MAJOR_AXIS units="km">numeric-value</SEMI_MAJOR_AXIS>
MEAN_MOTION	rev/day	<MEAN_MOTION units="rev/day">numeric-value</MEAN_MOTION>
INCLINATION	deg	<INCLINATION units="deg">numeric-value</INCLINATION>
RA_OF_ASC_NODE	deg	<RA_OF_ASC_NODE units="deg">numeric-value</RA_OF_ASC_NODE>
ARG_OF_PERICENTER	deg	<ARG_OF_PERICENTER units="deg">numeric-value</ARG_OF_PERICENTER>
MEAN_ANOMALY	deg	<MEAN_ANOMALY units="deg">numeric-value</MEAN_ANOMALY>
GM	km**3/s**2	<GM units="km**3/s**2">numeric-value</GM>
MASS	kg	<MASS units="kg">numeric-value</MASS>
SOLAR_RAD_AREA	m**2	<SOLAR_RAD_AREA units="m**2">numeric-value</SOLAR_RAD_AREA>
DRAG_AREA	m**2	<DRAG_AREA units="m**2">numeric-value</DRAG_AREA>
BSTAR	1/ER	<BSTAR units="1/ER">numeric-value</BSTAR>
MEAN_MOTION_DOT	rev/day**2	<MEAN_MOTION_DOT units="rev/day**2">numeric-value</MEAN_MOTION_DOT>
MEAN_MOTION_DDOT	rev/day**3	<MEAN_MOTION_DDOT units="rev/day**3">numeric-value</MEAN_MOTION_DDOT>
CX_X, CY_X, CY_Y, CZ_X, CZ_Y, CZ_Z	km**2	<CX_X units="km**2">numeric-value</CX_X>
CX_DOT_X, CX_DOT_Y, CX_DOT_Z, CY_DOT_X, CY_DOT_Y, CY_DOT_Z, CZ_DOT_X, CZ_DOT_Y, CZ_DOT_Z	km**2/s	<CX_DOT_X units="km**2/s">numeric-value</CX_DOT_X>
CX_DOT_X_DOT, CY_DOT_X_DOT, CY_DOT_Y_DOT, CZ_DOT_X_DOT, CZ_DOT_Y_DOT, CZ_DOT_Z_DOT	km**2/s**2	<CX_DOT_X_DOT units="km**2/s**2">numeric-value</CX_DOT_X_DOT>

4.11.13 SPECIAL TAGS IN THE OMM BODY

NOTE – In addition to the OMM keywords specified in reference [5], there are several special tags associated with the OMM body as described in the next few subsections. The information content in the OMM is separated into constructs described in reference [5] as ‘logical blocks’. Special tags in the OMM are used to encapsulate the information in the logical blocks of the OMM.

4.11.13.1 The NDM/XML tags used to delimit the logical blocks of the OMM shall be drawn from table 4-9.

Table 4-9: Special Tags Used in the OMM Body

OMM Logical Block	Associated NDM/XML OMM Tag
Mean Keplerian Elements	<meanElements>
Spacecraft Parameters	<spacecraftParameters>
TLE Parameters	<tleParameters>
Covariance Matrix	<covarianceMatrix>
User Defined Parameters	<userDefinedParameters>

4.11.13.2 Between the begin tag and end tag (e.g., between <spacecraftParameters> and </spacecraftParameters>), the user must place the keywords required by the specific logical block as specified in reference [5].

NOTE – The use of <userDefinedParameters> is described in 4.13.

4.12 CREATING AN OPM INSTANTIATION

4.12.1 An OPM instantiation shall be delimited with the <opm></opm> root element tags using the standard attributes documented in 4.3.

NOTE – Figure B-6 in annex B shows an example OPM instantiation.

4.12.2 The final attributes of the <opm> tag shall be ‘id’ and ‘version’.

4.12.3 The ‘id’ attribute shall be ‘id="CCSDS_OPM_VERS"’.

4.12.4 The ‘version’ attribute for the version of the OPM described in reference [5] shall be ‘version="2.0"’.

4.12.5 The standard NDM header shall follow the <opm> tag (see 4.3.4).

4.12.6 The OPM <body> shall consist of a single <segment> (see figure 3-1).

4.12.7 The segment shall consist of a <metadata> section and a <data> section.

4.12.8 The keywords in the <metadata> and <data> sections shall be those specified in reference [5].

NOTE – The rules for including any of the keyword tags in the instantiation are the same as those specified for the OPM in reference [5].

4.12.9 Tags for keywords specified in reference [5] shall be all uppercase as in reference [5].

4.12.10 Several of the NDM/XML OPM keywords may have a unit attribute, if desired by the OPM producer.

4.12.11 In all cases, the units shall match those defined in reference [5].

4.12.12 Table 4-10 lists the keyword tags for which units may be specified.

Table 4-10: OPM Tags with Units

Keyword	Units	Example
X	km	<X units="km">numeric-value</X>
Y	km	<Y units="km">numeric-value</Y>
Z	km	<Z units="km">numeric-value</Z>
X_DOT	km/s	<X_DOT units="km/s">numeric-value</X_DOT>
Y_DOT	km/s	<Y_DOT units="km/s">numeric-value</Y_DOT>
Z_DOT	km/s	<Z_DOT units="km/s">numeric-value</Z_DOT>
SEMI_MAJOR_AXIS	km	<SEMI_MAJOR_AXIS units="km">numeric-value</SEMI_MAJOR_AXIS>
INCLINATION	deg	<INCLINATION units="deg">numeric-value</INCLINATION>
RA_OF_ASC_NODE	deg	<RA_OF_ASC_NODE units="deg">numeric-value</RA_OF_ASC_NODE>
ARG_OF_PERICENTER	deg	<ARG_OF_PERICENTER units="deg">numeric-value</ARG_OF_PERICENTER>
TRUE_ANOMALY	deg	<TRUE_ANOMALY units="deg">numeric-value</TRUE_ANOMALY>
MEAN_ANOMALY	deg	<MEAN ANOMALY units="deg">numeric-value</MEAN ANOMALY>
GM	km**3/s**2	<GM units="km**3/s**2">numeric-value</GM>
MASS	kg	<MASS units="kg">numeric-value</MASS>
SOLAR_RAD_AREA	m**2	<SOLAR_RAD_AREA units="m**2">numeric-value</SOLAR_RAD_AREA>
DRAG_AREA	m**2	<DRAG_AREA units="m**2">numeric-value</DRAG_AREA>
CX_X, CY_X, CY_Y, CZ_X, CZ_Y, CZ_Z	km**2	<CX_X units="km**2">numeric-value</CX_X>
CX_DOT_X, CX_DOT_Y, CX_DOT_Z, CY_DOT_X, CY_DOT_Y, CY_DOT_Z, CZ_DOT_X, CZ_DOT_Y, CZ_DOT_Z	km**2/s	<CX_DOT_X units="km**2/s">numeric-value</CX_DOT_X>
CX_DOT_X_DOT, CY_DOT_X_DOT, CY_DOT_Y_DOT, CZ_DOT_X_DOT, CZ_DOT_Y_DOT, CZ_DOT_Z_DOT,	km**2/s**2	<CX_DOT_X_DOT units="km**2/s**2">numeric-value</CX_DOT_X_DOT>
MAN_DURATION	s	<MAN_DURATION units="s">numeric-value</MAN_DURATION>
MAN_DELTA_MASS	kg	<MAN_DELTA_MASS units="kg">numeric-

Keyword	Units	Example
		value</MAN DELTA MASS>
MAN_DV_1	km/s	<MAN_DV_1 units="km/s">numeric-value</MAN_DV_1>
MAN_DV_2	km/s	<MAN_DV_2 units="km/s">numeric-value</MAN_DV_2>
MAN_DV_3	km/s	<MAN_DV_3 units="km/s">numeric-value</MAN_DV_3>

4.12.13 SPECIAL TAGS IN THE OPM BODY

NOTE – In addition to the OPM keywords specified in reference [5], there are several special tags associated with the OPM body as described in the next few subsections. The information content in the OPM is separated into constructs described in reference [5] as ‘logical blocks’. Special tags in the OPM are used to encapsulate the information in the logical blocks of the OPM.

4.12.13.1 The NDM/XML tags used to delimit the logical blocks of the OPM shall be drawn from table 4-11.

Table 4-11: Special Tags Used in the OPM Body

OPM Logical Block	Associated NDM/XML OPM Tag
State Vector	<stateVector>
Keplerian Elements	<keplerianElements>
Spacecraft Parameters	<spacecraftParameters>
Covariance Matrix	<covarianceMatrix>
Maneuver Parameters	<maneuverParameters>
User Defined Parameters	<userDefinedParameters>

4.12.13.2 Between the begin tag and end tag (e.g., between <spacecraftParameters> and </spacecraftParameters>), the user shall place the keywords required by the specific logical block as specified in reference [5].

NOTE – The use of <userDefinedParameters> is defined in 4.13.

4.13 USER DEFINED PARAMETERS

NOTE – The ODM Version 2.0 (reference [5]) introduced the notion of ‘user-defined parameters’. These parameters are situation specific and are not standardized. Accordingly, the use of user-defined parameters is not encouraged. Because these parameters are not known to the schema, there is only one very broad keyword offered in the NDM/XML: <USER_DEFINED>.

4.13.1 GENERAL

4.13.1.1 User-defined parameters, if utilized, must be specified in ICDs between the exchange participants.

4.13.1.2 User-defined parameters shall only appear in instantiations of the OMM and the OPM Version 2.0.

4.13.1.3 User-defined parameters shall not appear in instantiations of the AEM, APM, CDM, OEM, or TDM.

4.13.1.4 User-defined parameters shall appear in a logical block that is offset with the tag set `<userDefinedParameters></userDefinedParameters>`.

4.13.1.5 Specific user-defined parameters in an NDM shall utilize the tag `<USER_DEFINED>`.

4.13.1.6 Following the `<userDefinedParameters>` tag, any number and order of `<USER_DEFINED>` tags may appear.

4.13.1.7 All information about the user-defined parameters shall be conveyed via one attribute of the `<USER_DEFINED>` tag (the attribute 'parameter') and the `<USER_DEFINED>` element value.

4.13.1.8 In the NDM/XML, the variable-length value associated with the parameter attribute shall be the string following 'USER_DEFINED_' in the associated KVN keyword.

4.13.1.9 The data type for the user-defined value shall be 'xsd:string', even if the actual user-defined parameter has a numeric value.

4.13.2 DISCUSSION

For example, the following KVN parameters might appear in an OMM or OPM:

```
USER_DEFINED_ATMOSPHERE_MODEL = MSISE90
USER_DEFINED_C3 = 29.376
USER_DEFINED_EARTH_RADIUS = 6378.1
USER_DEFINED_3RD_BODY_PERTURBATION = JUPITER
```

These parameters would appear in an NDM/XML representation as:

```
<userDefinedParameters>
  <USER_DEFINED parameter="ATMOSPHERE_MODEL">MSISE90</USER_DEFINED>
  <USER_DEFINED parameter="C3">29.376</USER_DEFINED>
  <USER_DEFINED parameter="EARTH_RADIUS">6378.1</USER_DEFINED>
  <USER_DEFINED parameter="3RD_BODY_PERTURBATION">JUPITER</USER_DEFINED>
</userDefinedParameters>
```

4.14 CREATING AN NDM COMBINED INSTANTIATION

4.14.1 OVERVIEW

It is possible to create an XML instance that incorporates any number of NDM messages from references listed in references [4]–[8] in a logical suite called an ‘NDM combined instantiation’. Such combined instantiations may be useful for some situations, for example:

- a constellation of spacecraft in which ephemeris data for all the spacecraft is combined in a single XML message;
- a spacecraft attitude that depends upon a particular orbital state (an APM and its associated OPM could be conveniently conveyed in a single NDM);
- an ephemeris message with the set of tracking data messages used in the orbit determination.

4.14.2 An NDM combined instantiation shall be delimited with the `<ndm></ndm>` root element tags instead of one of the individual message tags.

4.14.3 The standard attributes documented in 4.3 shall be used with the `<ndm>` tag, with the exception that neither ‘id’ nor ‘version’ attributes are associated with the `<ndm>` tag.

4.14.4 In the NDM combined instantiation, the only attributes that shall appear on the constituent message tags are the ‘id’ and ‘version’ attributes, as described in the subsections 4.8 through 4.12.

4.14.5 Between the `<ndm></ndm>` tags, the desired messages described in 4.8 through 4.12 may be combined.

4.14.6 Any combination of constituent NDM message types may be used in an NDM combined instantiation.

4.14.7 An NDM combined instantiation should consist of at least one constituent message from the references listed in references [4]–[8].

4.14.8 DISCUSSION

Figures 4-1 through 4-3 illustrate the basic structure of an NDM combined instantiation. Figure 4-1 has removed all detail to contrast the single message NDM with an NDM combined instantiation. In figure 4-2, the basic structure of an NDM combined instantiation is graphically illustrated. As shown in figure 4-3, in an NDM combined instantiation, the individual message tags still have the ‘id’ and ‘version’ attributes, but the namespace attributes and schema location attributes are associated with the `<ndm>` root element.

Single Message NDM	NDM Combined Instantiation
<pre><opm> <header> </header> <body> </body> </opm></pre>	<pre><ndm> <opm> <header> </header> <body> </body> </opm> <apm> <header> </header> <body> </body> </apm> </ndm></pre>

Figure 4-1: Comparison of Single Message NDM with NDM Combined Instantiation

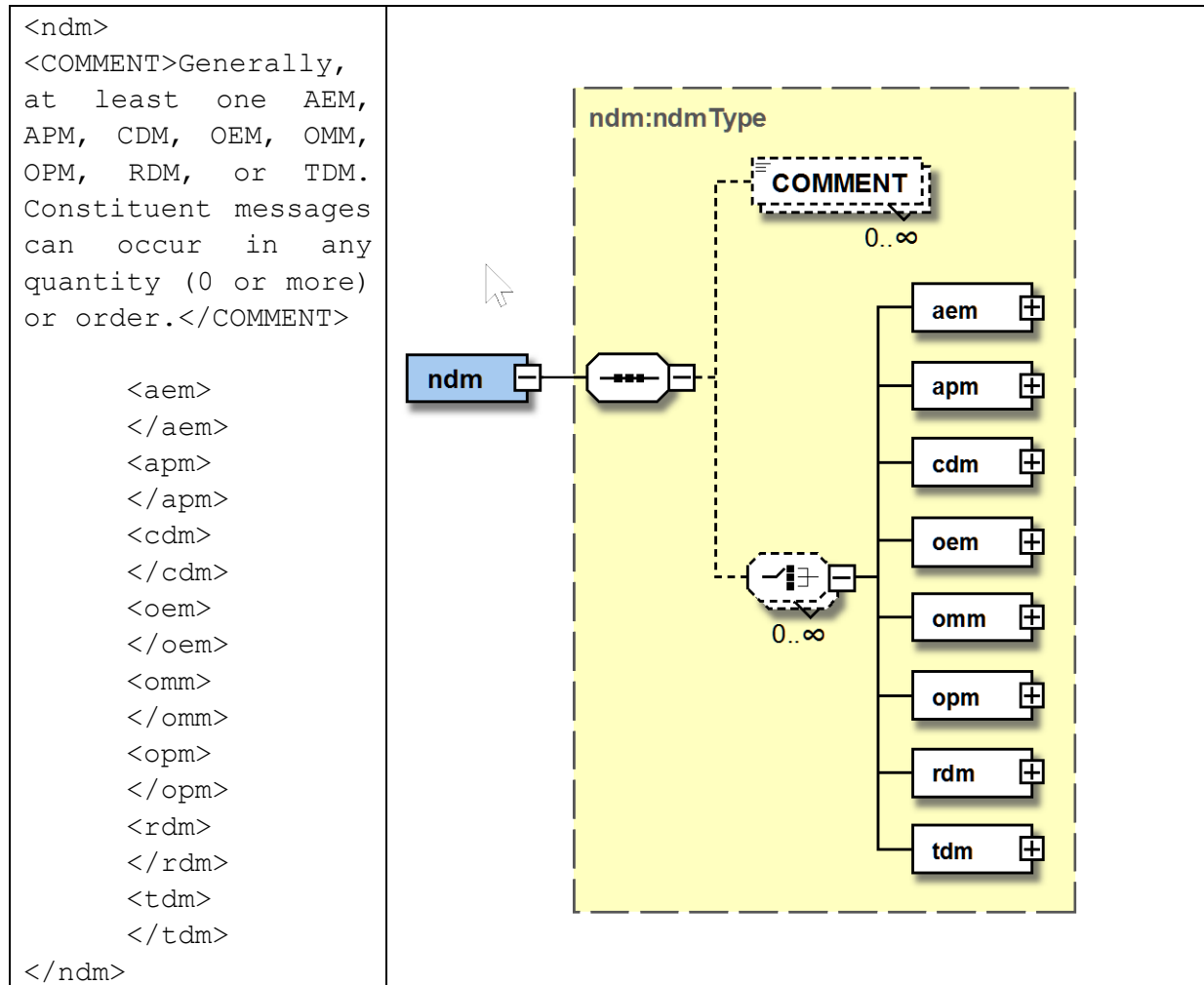


Figure 4-2: NDM Combined Instantiation Basic Structure

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

```
<?xml version="1.0" encoding="UTF-8"?>
<ndm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xmlns:ndm="urn:ccsds:schema:ndmxml"
      xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_unqualified/ndmxml-
2.0.0-master-2.0.xsd">

  <apm id="CCSDS_APM_VERS" version="1.0">
    <header>
    </header>
    <body>
    </body>
  </apm>

  <aem id="CCSDS_AEM_VERS" version="1.0">
    <header>
    </header>
    <body>
    </body>
  </aem>

  <cdm id="CCSDS_CDM_VERS" version="1.0">
    <header>
    </header>
    <body>
    </body>
  </cdm>

  <opm id="CCSDS_OPM_VERS" version="2.0">
    <header>
    </header>
    <body>
    </body>
  </opm>

  <omm id="CCSDS_OMM_VERS" version="2.0">
    <header>
    </header>
    <body>
    </body>
  </omm>

  <oem id="CCSDS_OEM_VERS" version="2.0">
    <header>
    </header>
    <body>
    </body>
  </oem>

  <rdm id="CCSDS_RDM_VERS" version="1.0">
    <header>
    </header>
    <body>
    </body>
  </rdm>

  <tdm id="CCSDS_TDM_VERS" version="2.0">
    <header>
    </header>
    <body>
    </body>
  </tdm>

</ndm>
```

Figure 4-3: NDM Combined Instantiation Showing Use of Attributes

ANNEX A

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

A1 SECURITY CONSIDERATIONS

A1.1 ANALYSIS OF SECURITY CONSIDERATIONS

This annex presents the results of an analysis of security considerations applied to the technologies specified in this Recommended Standard.

A1.2 CONSEQUENCES OF NOT APPLYING SECURITY TO THE TECHNOLOGY

The consequences of not applying security to the systems and networks on which this Recommended Standard is implemented could include potential loss, corruption, and theft of data. Because it is possible to utilize these messages in orbit determination, in preparing pointing and frequency predicts used during spacecraft commanding, and in collision avoidance studies, the consequences of not applying security to the systems and networks on which this Recommended Standard is implemented could include compromise or loss of the mission if malicious tampering of a particularly severe nature occurs.

A1.3 POTENTIAL THREATS AND ATTACK SCENARIOS

Potential threats or attack scenarios include, but are not limited to, (a) unauthorized access to the programs/processes that generate and interpret the messages, (b) unauthorized access to the messages during transmission between exchange partners, and (c) modification of the messages between partners. Protection from unauthorized access during transmission is especially important if the mission utilizes open ground networks such as the Internet to provide ground station connectivity for the exchange of data formatted in compliance with this Recommended Standard. It is strongly recommended that potential threats or attack scenarios applicable to the systems and networks on which this Recommended Standard is implemented be addressed by the management of those systems and networks.

A1.4 DATA PRIVACY

Privacy of data formatted in compliance with the specifications of this Recommended Standard should be assured by the systems and networks on which this Recommended Standard is implemented.

A1.5 DATA INTEGRITY

Integrity of data formatted in compliance with the specifications of this Recommended Standard should be assured by the systems and networks on which this Recommended Standard is implemented.

A1.6 AUTHENTICATION OF COMMUNICATING ENTITIES

Authentication of communicating entities involved in the transport of data that complies with the specifications of this Recommended Standard should be provided by the systems and networks on which this Recommended Standard is implemented.

A1.7 DATA TRANSFER BETWEEN COMMUNICATING ENTITIES

The transfer of data formatted in compliance with this Recommended Standard between communicating entities should be accomplished via secure mechanisms approved by the Information Technology Security functionaries of exchange participants.

A1.8 CONTROL OF ACCESS TO RESOURCES

Control of access to resources should be managed by the systems upon which originator formatting and recipient processing are performed.

A1.9 AUDITING OF RESOURCE USAGE

Auditing of resource usage should be handled by the management of systems and networks on which this Recommended Standard is implemented.

A1.10 UNAUTHORIZED ACCESS

Unauthorized access to the programs/processes that generate and interpret the messages should be prohibited in order to minimize potential threats and attack scenarios.

A1.11 DATA SECURITY IMPLEMENTATION SPECIFICS

Specific information-security interoperability provisions that apply between agencies and other independent users involved in an exchange of data formatted in compliance with this Recommended Standard should be specified in an ICD.

A2 SANA CONSIDERATIONS

The following NDM/XML related items are registered with the SANA Operator.

- The NDM/XML schemas (see reference [3]).

The values for certain fields in an XML instantiation are also registered with SANA. The details as to these are incorporated in the ‘Security, SANA, and Patent Considerations’ annexes of references [4]–[8].

NOTE – This annex subsection is not present in older Navigation Working Group standards published prior to 2010.

The general policy for changes to the NDM/XML schemas is Expert Review by the Working Group or Area responsible for the NDM/XML standard. Any NDM/XML schema changes in the future will result in supersession of the older schema versions by the newer versions. Older versions will be available for download at <https://cwe.ccsds.org/moims/docs/MOIMS-NAV/NDM-XML-Schema-Archive/>.

The registration rule for new entries in the registry is the approval of new requests by the CCSDS Area or Working Group responsible for the maintenance of the NDM/XML at the time of the request. New requests for this registry should be sent to SANA (<mailto:info@sanaregistry.org>).

A3 PATENT CONSIDERATIONS

The recommendations of this document have no patent issues.

ANNEX B

EXAMPLE NDM/XML SCHEMA INSTANTIATIONS

(INFORMATIVE)

B1 GENERAL

The schema sets associated with this standard are available via the CCSDS SANA repository:

- Overall Schema link: <https://sanaregistry.org/r/ndmxml/>
 - Schemas with elementFormDefault="unqualified":
https://sanaregistry.org/r/ndmxml_unqualified/
 - Schemas with elementFormDefault="qualified":
https://sanaregistry.org/r/ndmxml_qualified/

An assortment of instantiations of the NDM/XML Schema Set is available on the CCSDS Web site's CWE:

- <https://cwe.ccsds.org/moims/docs/MOIMS-NAV/Test-Messages/XML>

These test XML instantiations in conjunction with elements of the NDM/XML schema set will validate successfully when validation-checked using the XML validator available in XML Spy Professional Edition.

B2 SAMPLE NDM/XML AEM

The following is a simple sample of an NDM/XML AEM:

```
<?xml version="1.0" encoding="UTF-8"?>
<aem xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_unqualified/ndmxml-2.0.0-
master-2.0.xsd"
id="CCSDS_AEM_VERS" version="1.0">
  <header>
    <COMMENT>This example corresponds to ADM Blue Book Figure 4-2</COMMENT>
    <CREATION_DATE>2008-071T17:09:49</CREATION_DATE>
    <ORIGINATOR>GSFC FDF</ORIGINATOR>
  </header>
  <body>
    <segment>
      <metadata>
        <COMMENT>This file was produced by M.R. Somebody, MS00 NAV/JPL, 2002 OCT
04.</COMMENT>
        <COMMENT>It is to be used for attitude reconstruction only. The relative accuracy
of these</COMMENT>
        <COMMENT>attitudes is 0.1 degrees per axis.</COMMENT>
        <OBJECT_NAME>ST5-224</OBJECT_NAME>
        <OBJECT_ID>2006224</OBJECT_ID>
        <CENTER_NAME>EARTH</CENTER_NAME>
        <REF_FRAME_A>J2000</REF_FRAME_A>
        <REF_FRAME_B>SC_BODY_1</REF_FRAME_B>
        <ATTITUDE_DIR>A2B</ATTITUDE_DIR>
        <TIME_SYSTEM>UTC</TIME_SYSTEM>
        <START_TIME>2006-090T05:00:00.071</START_TIME>
        <USEABLE_START_TIME>2006-090T05:00:00.071</USEABLE_START_TIME>
        <USEABLE_STOP_TIME>2006-090T05:00:00.946</USEABLE_STOP_TIME>
        <STOP_TIME>2006-090T05:00:00.946</STOP_TIME>
        <ATTITUDE_TYPE>SPIN</ATTITUDE_TYPE>
      </metadata>
      <data>
        <COMMENT>Spin KF ground solution, SPINKF rates</COMMENT>
        <attitudeState>
          <spin>
            <EPOCH>2006-090T05:00:00.071</EPOCH>
            <SPIN_ALPHA>2.6862511e+002</SPIN_ALPHA>
            <SPIN_DELTA>6.8448486e+001</SPIN_DELTA>
            <SPIN_ANGLE>1.5969509e+002</SPIN_ANGLE>
            <SPIN_ANGLE_VEL>-1.0996528e+002</SPIN_ANGLE_VEL>
          </spin>
        </attitudeState>
        <attitudeState>
          <spin>
            <EPOCH>2006-090T05:00:00.196</EPOCH>
            <SPIN_ALPHA>2.6863990e+002</SPIN_ALPHA>
            <SPIN_DELTA>6.8432197e+001</SPIN_DELTA>
            <SPIN_ANGLE>1.4593720e+002</SPIN_ANGLE>
            <SPIN_ANGLE_VEL>-1.0996493e+002</SPIN_ANGLE_VEL>
          </spin>
        </attitudeState>
        <attitudeState>
          <spin>
            <EPOCH>2006-090T05:00:00.321</EPOCH>
            <SPIN_ALPHA>2.6864591e+002</SPIN_ALPHA>
            <SPIN_DELTA>6.8412960e+001</SPIN_DELTA>
            <SPIN_ANGLE>1.3218766e+002</SPIN_ANGLE>
            <SPIN_ANGLE_VEL>-1.0996455e+002</SPIN_ANGLE_VEL>
          </spin>
        </attitudeState>
      </data>
    </segment>
  </body>
</aem>
```

Figure B-1: Sample NDM/XML AEM

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

```
<attitudeState>
  <spin>
    <EPOCH>2006-090T05:00:00.446</EPOCH>
    <SPIN_ALPHA>2.6863697e+002</SPIN_ALPHA>
    <SPIN_DELTA>6.8392049e+001</SPIN_DELTA>
    <SPIN_ANGLE>1.1845280e+002</SPIN_ANGLE>
    <SPIN_ANGLE_VEL>-1.0996402e+002</SPIN_ANGLE_VEL>
  </spin>
</attitudeState>
<attitudeState>
  <spin>
    <EPOCH>2006-090T05:00:00.571</EPOCH>
    <SPIN_ALPHA>2.6861072e+002</SPIN_ALPHA>
    <SPIN_DELTA>6.8371266e+001</SPIN_DELTA>
    <SPIN_ANGLE>1.0473305e+002</SPIN_ANGLE>
    <SPIN_ANGLE_VEL>-1.0996370e+002</SPIN_ANGLE_VEL>
  </spin>
</attitudeState>
<attitudeState>
  <spin>
    <EPOCH>2006-090T05:00:00.696</EPOCH>
    <SPIN_ALPHA>2.6856625e+002</SPIN_ALPHA>
    <SPIN_DELTA>6.8353279e+001</SPIN_DELTA>
    <SPIN_ANGLE>9.1030304e+001</SPIN_ANGLE>
    <SPIN_ANGLE_VEL>-1.0996339e+002</SPIN_ANGLE_VEL>
  </spin>
</attitudeState>
<attitudeState>
  <spin>
    <EPOCH>2006-090T05:00:00.821</EPOCH>
    <SPIN_ALPHA>2.6850631e+002</SPIN_ALPHA>
    <SPIN_DELTA>6.8340398e+001</SPIN_DELTA>
    <SPIN_ANGLE>7.7341548e+001</SPIN_ANGLE>
    <SPIN_ANGLE_VEL>-1.0996317e+002</SPIN_ANGLE_VEL>
  </spin>
</attitudeState>
<attitudeState>
  <spin>
    <EPOCH>2006-090T05:00:00.946</EPOCH>
    <SPIN_ALPHA>2.6843571e+002</SPIN_ALPHA>
    <SPIN_DELTA>6.8332398e+001</SPIN_DELTA>
    <SPIN_ANGLE>6.3662262e+001</SPIN_ANGLE>
    <SPIN_ANGLE_VEL>-1.0996304e+002</SPIN_ANGLE_VEL>
  </spin>
</attitudeState>
</data>
</segment>
</body>
</aem>
```

Figure B-1: Sample NDM/XML AEM (continued)

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

```

<?xml version="1.0" encoding="UTF-8"?>
<aem xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_unqualified/ndmxml-
  2.0.0-master-2.0.xsd"
  id="CCSDS_AEM_VERS" version="1.0">

  <header>
    <COMMENT>This example shows an AEM with a rotation</COMMENT>
    <CREATION_DATE>2008-071T17:09:49</CREATION_DATE>
    <ORIGINATOR>NASA</ORIGINATOR>
  </header>
  <body>
    <segment>
      <metadata>
        <COMMENT>The relative accuracy of these</COMMENT>
        <COMMENT>attitudes is 0.1 degrees per axis.</COMMENT>
        <OBJECT_NAME>FICTITIOUS</OBJECT_NAME>
        <OBJECT_ID>2020-224A</OBJECT_ID>
        <CENTER_NAME>EARTH</CENTER_NAME>
        <REF_FRAME_A>J2000</REF_FRAME_A>
        <REF_FRAME_B>SC_BODY_1</REF_FRAME_B>
        <ATTITUDE_DIR>A2B</ATTITUDE_DIR>
        <TIME_SYSTEM>UTC</TIME_SYSTEM>
        <START_TIME>2020-090T05:00:00.071</START_TIME>
        <STOP_TIME>2020-090T05:00:00.946</STOP_TIME>
        <ATTITUDE_TYPE>EULER_ANGLE/RATE</ATTITUDE_TYPE>
      </metadata>
      <data>
        <attitudeState>
          <eulerAngleRate>
            <EPOCH>2020-090T05:00:00.071</EPOCH>
            <rotationAngles>
              <rotation1 angle="X_ANGLE" units="deg">45</rotation1>
              <rotation2 angle="Y_ANGLE" units="deg">0.9</rotation2>
              <rotation3 angle="Z_ANGLE" units="deg">15</rotation3>
            </rotationAngles>
            <rotationRates>
              <rotation1 rate="X_RATE">4.5</rotation1>
              <rotation2 rate="Y_RATE">0.123</rotation2>
              <rotation3 rate="Z_RATE">15</rotation3>
            </rotationRates>
          </eulerAngleRate>
        </attitudeState>
        <attitudeState>
          <eulerAngleRate>
            <EPOCH>2020-090T05:00:00.946</EPOCH>
            <rotationAngles>
              <rotation1 angle="X_ANGLE" units="deg">50</rotation1>
              <rotation2 angle="Y_ANGLE" units="deg">1.9</rotation2>
              <rotation3 angle="Z_ANGLE" units="deg">1.5</rotation3>
            </rotationAngles>
            <rotationRates>
              <rotation1 rate="X_RATE">1.0</rotation1>
              <rotation2 rate="Y_RATE">0.123</rotation2>
              <rotation3 rate="Z_RATE">1.5</rotation3>
            </rotationRates>
          </eulerAngleRate>
        </attitudeState>
      </data>
    </segment>
  </body>
</aem>

```

Figure B-2: Sample NDM/XML AEM with Rotation

B3 SAMPLE NDM/XML APM

The following is a simple sample of an NDM/XML APM:

```
<?xml version="1.0" encoding="UTF-8"?>
<apm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_unqualified/ndmxml-
2.0.0-master-2.0.xsd"
      id="CCSDS_APM_VERS" version="1.0">

  <header>
    <COMMENT>This example corresponds to ADM Blue Book Figure 3-8</COMMENT>
    <CREATION_DATE>2004-02-14T19:23:57</CREATION_DATE>
    <ORIGINATOR>JPL</ORIGINATOR>
  </header>
  <body>
    <segment>
      <metadata>
        <OBJECT_NAME>MARS SPIRIT</OBJECT_NAME>
        <OBJECT_ID>2004-003A</OBJECT_ID>
        <CENTER_NAME>EARTH</CENTER_NAME>
        <TIME_SYSTEM>UTC</TIME_SYSTEM>
      </metadata>
      <data>
        <COMMENT>GEOCENTRIC, CARTESIAN, EARTH FIXED</COMMENT>
        <COMMENT>OBJECT_ID: 2004-003</COMMENT>
        <COMMENT>$ITIM = 2004 JAN 14 22:26:18.400000, original launch 14:36</COMMENT>
        <COMMENT>Generated by JPL</COMMENT>
        <COMMENT>Current attitude for orbit 20 and attitude maneuver</COMMENT>
        <COMMENT>planning data.</COMMENT>
        <COMMENT>Attitude state quaternion</COMMENT>
        <quaternionState>
          <EPOCH>2004-02-14T14:28:15.1172</EPOCH>
          <Q_FRAME_A>INSTRUMENT_A</Q_FRAME_A>
          <Q_FRAME_B>ITRF-97</Q_FRAME_B>
          <Q_DIR>A2B</Q_DIR>
          <quaternion>
            <Q1>0.03123</Q1>
            <Q2>0.78543</Q2>
            <Q3>0.39158</Q3>
            <QC>0.47832</QC>
          </quaternion>
        </quaternionState>
        <eulerElementsThree>
          <COMMENT>Attitude specified as Euler elements</COMMENT>
          <EULER_FRAME_A>INSTRUMENT_A</EULER_FRAME_A>
          <EULER_FRAME_B>ITRF-97</EULER_FRAME_B>
          <EULER_DIR>A2B</EULER_DIR>
          <EULER_ROT_SEQ>312</EULER_ROT_SEQ>
          <RATE_FRAME>EULER_FRAME_A</RATE_FRAME>
          <rotationAngles>
            <rotation1 angle="Z_ANGLE" units="deg">-53.3688</rotation1>
            <rotation2 angle="X_ANGLE" units="deg">139.7527</rotation2>
            <rotation3 angle="Y_ANGLE" units="deg">25.0658</rotation3>
          </rotationAngles>
          <rotationRates>
            <rotation1 rate="Z_RATE" units="deg/s">0.02156</rotation1>
            <rotation2 rate="X_RATE" units="deg/s">0.1045</rotation2>
            <rotation3 rate="Y_RATE" units="deg/s">0.03214</rotation3>
          </rotationRates>
        </eulerElementsThree>
      </data>
    </segment>
  </body>
</apm>
```

Figure B-3: Sample NDM/XML APM

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

```
</eulerElementsThree>
<spacecraftParameters>
  <COMMENT>Spacecraft Parameters</COMMENT>
  <I11 units="kg*m**2">6080.0</I11>
  <I22 units="kg*m**2">5245.5</I22>
  <I33 units="kg*m**2">8067.3</I33>
  <I12 units="kg*m**2">-135.9</I12>
  <I13 units="kg*m**2">89.3</I13>
  <I23 units="kg*m**2">-90.7</I23>
</spacecraftParameters>
<maneuverParameters>
  <COMMENT> Data follows for 1 planned maneuver.</COMMENT>
  <COMMENT> First attitude maneuver for: MARS SPIRIT</COMMENT>
  <COMMENT> Impulsive, torque direction fixed in body frame</COMMENT>
  <MAN_EPOCH_START>2004-02-14T14:29:00.5098</MAN_EPOCH_START>
  <MAN_DURATION units="s">3</MAN_DURATION>
  <MAN_REF_FRAME>INSTRUMENT_A</MAN_REF_FRAME>
  <MAN_TOR_1 units="N*m">-1.25</MAN_TOR_1>
  <MAN_TOR_2 units="N*m">-0.5</MAN_TOR_2>
  <MAN_TOR_3 units="N*m">0.5</MAN_TOR_3>
</maneuverParameters>
</data>
</segment>
</body>
</apm>
```

Figure B-3: Sample NDM/XML APM (continued)

B4 SAMPLE NDM/XML OEM

The following is a simple sample of an NDM/XML OEM:

```

<?xml version="1.0" encoding="UTF-8"?>
<oem xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_unqualified/ndmxml-
  2.0.0-master-2.0.xsd"
  id="CCSDS_OEM_VERS" version="2.0">

  <header>
    <COMMENT>THIS EXAMPLE CONFORMS TO FIGURE 5-2 IN 502.0-B-2</COMMENT>
    <COMMENT>OEM WITH OPTIONAL ACCELERATIONS CAN ONLY BE OEM VERSION 2.0</COMMENT>
    <CREATION_DATE>1996-11-04T17:22:31</CREATION_DATE>
    <ORIGINATOR>NASA/JPL</ORIGINATOR>
  </header>
  <body>
    <segment>
      <metadata>
        <OBJECT_NAME>MARS GLOBAL SURVEYOR</OBJECT_NAME>
        <OBJECT_ID>1996-062A</OBJECT_ID>
        <CENTER_NAME>MARS BARYCENTER</CENTER_NAME>
        <REF_FRAME>EME2000</REF_FRAME>
        <TIME_SYSTEM>UTC</TIME_SYSTEM>
        <START_TIME>1996-12-18T12:00:00.331</START_TIME>
        <USEABLE_START_TIME>1996-12-18T12:10:00.331</USEABLE_START_TIME>
        <USEABLE_STOP_TIME>1996-12-28T21:23:00.331</USEABLE_STOP_TIME>
        <STOP_TIME>1996-12-28T21:28:00.331</STOP_TIME>
        <INTERPOLATION>HERMITE</INTERPOLATION>
        <INTERPOLATION_DEGREE>7</INTERPOLATION_DEGREE>
      </metadata>
      <data>
        <COMMENT>Produced by M.R. Sombedody, MSOO NAV/JPL, 1996 OCT 11. It is</COMMENT>
        <COMMENT>to be used for DSN scheduling purposes only.</COMMENT>
        <stateVector>
          <EPOCH>1996-12-18T12:00:00.331</EPOCH>
          <X>2789.6</X>
          <Y>-280.0</Y>
          <Z>-1746.8</Z>
          <X_DOT>4.73</X_DOT>
          <Y_DOT>-2.50</Y_DOT>
          <Z_DOT>-1.04</Z_DOT>
          <X_DDOT>0.008</X_DDOT>
          <Y_DDOT>0.001</Y_DDOT>
          <Z_DDOT>-0.159</Z_DDOT>
        </stateVector>
        <stateVector>
          <EPOCH>1996-12-18T12:01:00.331</EPOCH>
          <X>2783.4</X>
          <Y>-308.1</Y>
          <Z>-1877.1</Z>
          <X_DOT>5.19</X_DOT>
          <Y_DOT>-2.42</Y_DOT>
          <Z_DOT>-2.00</Z_DOT>
          <X_DDOT>0.008</X_DDOT>
          <Y_DDOT>0.001</Y_DDOT>
          <Z_DDOT>0.001</Z_DDOT>
        </stateVector>
      </data>
    </segment>
  </body>
</oem>

```

Figure B-4: Sample NDM/XML OEM

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

```

<stateVector>
  <EPOCH>1996-12-18T12:02:00.331</EPOCH>
  <X>2776.0</X>
  <Y>-336.9</Y>
  <Z>-2008.7</Z>
  <X_DOT>5.64</X_DOT>
  <Y_DOT>-2.34</Y_DOT>
  <Z_DOT>-1.95</Z_DOT>
  <X_DDOT>0.008</X_DDOT>
  <Y_DDOT>0.001</Y_DDOT>
  <Z_DDOT>0.159</Z_DDOT>
</stateVector>
<stateVector>
  <EPOCH>1996-12-28T21:28:00.331</EPOCH>
  <X>-3881.0</X>
  <Y>564.0</Y>
  <Z>-682.8</Z>
  <X_DOT>-3.29</X_DOT>
  <Y_DOT>-3.67</Y_DOT>
  <Z_DOT>1.64</Z_DOT>
  <X_DDOT>-0.003</X_DDOT>
  <Y_DDOT>0.000</Y_DDOT>
  <Z_DDOT>0.000</Z_DDOT>
</stateVector>
<covarianceMatrix>
  <EPOCH></EPOCH>
  <COV_REF_FRAME>ITRF-97</COV_REF_FRAME>
  <CX_X>0.316</CX_X>
  <CY_X>0.722</CY_X>
  <CY_Y>0.518</CY_Y>
  <CZ_X>0.202</CZ_X>
  <CZ_Y>0.715</CZ_Y>
  <CZ_Z>0.002</CZ_Z>
  <CX_DOT_X>0.912</CX_DOT_X>
  <CX_DOT_Y>0.306</CX_DOT_Y>
  <CX_DOT_Z>0.276</CX_DOT_Z>
  <CX_DOT_X_DOT>0.797</CX_DOT_X_DOT>
  <CY_DOT_X>0.562</CY_DOT_X>
  <CY_DOT_Y>0.899</CY_DOT_Y>
  <CY_DOT_Z>0.022</CY_DOT_Z>
  <CY_DOT_X_DOT>0.079</CY_DOT_X_DOT>
  <CY_DOT_Y_DOT>0.415</CY_DOT_Y_DOT>
  <CZ_DOT_X>0.245</CZ_DOT_X>
  <CZ_DOT_Y>0.965</CZ_DOT_Y>
  <CZ_DOT_Z>0.950</CZ_DOT_Z>
  <CZ_DOT_X_DOT>0.435</CZ_DOT_X_DOT>
  <CZ_DOT_Y_DOT>0.621</CZ_DOT_Y_DOT>
  <CZ_DOT_Z_DOT>0.991</CZ_DOT_Z_DOT>
</covarianceMatrix>
</data>
</segment>
</body>
</oem>

```

Figure B-4: Sample NDM/XML OEM (continued)

B5 SAMPLE NDM/XML OMM

The following is a simple sample of an NDM/XML OMM:

```

<?xml version="1.0" encoding="UTF-8"?>
<omm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_unqualified/ndmxml-
2.0.0-master-2.0.xsd"
      id="CCSDS_OMM_VERS" version="2.0">

  <header>
    <COMMENT>THIS EXAMPLE CONFORMS TO FIGURE 4-3 IN 502.0-B-2</COMMENT>
    <CREATION_DATE>2007-065T16:00:00</CREATION_DATE>
    <ORIGINATOR>NOAA/USA</ORIGINATOR>
  </header>

  <body>
    <segment>
      <metadata>
        <OBJECT_NAME>GOES-9</OBJECT_NAME>
        <OBJECT_ID>1995-025A</OBJECT_ID>
        <CENTER_NAME>EARTH</CENTER_NAME>
        <REF_FRAME>TEME</REF_FRAME>
        <TIME_SYSTEM>UTC</TIME_SYSTEM>
        <MEAN_ELEMENT_THEORY>TLE</MEAN_ELEMENT_THEORY>
      </metadata>

      <data>
        <meanElements>
          <EPOCH>2007-064T10:34:41.4264</EPOCH>
          <MEAN_MOTION>1.00273272</MEAN_MOTION>
          <ECCENTRICITY>0.0005013</ECCENTRICITY>
          <INCLINATION>3.0539</INCLINATION>
          <RA_OF_ASC_NODE>81.7939</RA_OF_ASC_NODE>
          <ARG_OF_PERICENTER>249.2363</ARG_OF_PERICENTER>
          <MEAN_ANOMALY>150.1602</MEAN_ANOMALY>
          <GM>398600.8</GM>
        </meanElements>
        <tleParameters>
          <NORAD_CAT_ID>23581</NORAD_CAT_ID>
          <ELEMENT_SET_NO>0925</ELEMENT_SET_NO>
          <REV_AT_EPOCH>4316</REV_AT_EPOCH>
          <BSTAR>0.0001</BSTAR>
          <MEAN_MOTION_DOT>-0.00000113</MEAN_MOTION_DOT>
          <MEAN_MOTION_DDOT>0.0</MEAN_MOTION_DDOT>
        </tleParameters>
      </data>
    </segment>
  </body>
</omm>

```

Figure B-5: Sample NDM/XML OMM

```

    <covarianceMatrix>
      <COV_REF_FRAME>TEME</COV_REF_FRAME>
      <CX_X>0.316</CX_X>
      <CY_X>0.722</CY_X>
      <CY_Y>0.518</CY_Y>
      <CZ_X>0.202</CZ_X>
      <CZ_Y>0.715</CZ_Y>
      <CZ_Z>0.002</CZ_Z>
      <CX_DOT_X>0.912</CX_DOT_X>
      <CX_DOT_Y>0.306</CX_DOT_Y>
      <CX_DOT_Z>0.276</CX_DOT_Z>
      <CX_DOT_X_DOT>0.797</CX_DOT_X_DOT>
      <CY_DOT_X>0.562</CY_DOT_X>
      <CY_DOT_Y>0.899</CY_DOT_Y>
      <CY_DOT_Z>0.022</CY_DOT_Z>
      <CY_DOT_X_DOT>0.079</CY_DOT_X_DOT>
      <CY_DOT_Y_DOT>0.415</CY_DOT_Y_DOT>
      <CZ_DOT_X>0.245</CZ_DOT_X>
      <CZ_DOT_Y>0.965</CZ_DOT_Y>
      <CZ_DOT_Z>0.950</CZ_DOT_Z>
      <CZ_DOT_X_DOT>0.435</CZ_DOT_X_DOT>
      <CZ_DOT_Y_DOT>0.621</CZ_DOT_Y_DOT>
      <CZ_DOT_Z_DOT>0.991</CZ_DOT_Z_DOT>
    </covarianceMatrix>
  </data>
</segment>
</body>
</omm>

```

Figure B-5: Sample NDM/XML OMM (continued)

B6 SAMPLE NDM/XML OPM

The following is a simple sample of an NDM/XML OPM:

```

<?xml version="1.0" encoding="UTF-8"?>
<opm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_unqualified/ndmxml-
2.0.0-master-2.0.xsd"
      id="CCSDS_OPM_VERS" version="2.0">

  <header>
    <COMMENT>THIS EXAMPLE CONFORMS TO FIGURE 3-1 IN 502.0-B-1</COMMENT>
    <CREATION_DATE>2001-11-06T09:23:57</CREATION_DATE>
    <ORIGINATOR>JAXA</ORIGINATOR>
  </header>
  <body>
    <segment>
      <metadata>
        <COMMENT>GEOCENTRIC, CARTESIAN, EARTH FIXED</COMMENT>
        <OBJECT_NAME>SPACECRAFT 5</OBJECT_NAME>
        <OBJECT_ID>1998-057A</OBJECT_ID>
        <CENTER_NAME>EARTH</CENTER_NAME>
        <REF_FRAME>ITRF-97</REF_FRAME>
        <TIME_SYSTEM>UTC</TIME_SYSTEM>
      </metadata>
      <data>
        <COMMENT>OBJECT_ID: 1998-057A</COMMENT>
        <COMMENT>$ITIM = 1998 OCT09 22:26:18.400, original launch time 21:58 </COMMENT>
        <COMMENT>$ITIM = 1998 OCT09 22:23:18.400, reflects -3mn shift 21:55 </COMMENT>
        <COMMENT>$ITIM = 1998 OCT09 22:28:18.400, reflects +5mn shift 22:00 </COMMENT>
        <COMMENT>$ITIM = 1998 OCT09 22:58:18.400, reflects +30mn shift 22:30 </COMMENT>
        <COMMENT>$ITIM = 1998 OCT09 23:18:18.400, reflects +20mn shift 22:50 </COMMENT>
        <stateVector>
          <EPOCH>1996-12-18T14:28:15.1172</EPOCH>
          <X>6503.514000</X>
          <Y>1239.647000</Y>
          <Z>-717.490000</Z>
          <X_DOT>-0.873160</X_DOT>
          <Y_DOT>8.740420</Y_DOT>
          <Z_DOT>-4.191076</Z_DOT>
        </stateVector>
        <spacecraftParameters>
          <MASS>3000.000000</MASS>
          <SOLAR_RAD_AREA>18.770000</SOLAR_RAD_AREA>
          <SOLAR_RAD_COEFF>1.000000</SOLAR_RAD_COEFF>
          <DRAG_AREA>18.770000</DRAG_AREA>
          <DRAG_COEFF>2.500000</DRAG_COEFF>
        </spacecraftParameters>
      </data>
    </segment>
  </body>
</opm>

```

Figure B-6: Sample NDM/XML OPM

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

```
<covarianceMatrix>
  <COV_REF_FRAME>ITRF-97</COV_REF_FRAME>
  <CX_X>0.316</CX_X>
  <CY_X>0.722</CY_X>
  <CY_Y>0.518</CY_Y>
  <CZ_X>0.202</CZ_X>
  <CZ_Y>0.715</CZ_Y>
  <CZ_Z>0.002</CZ_Z>
  <CX_DOT_X>0.912</CX_DOT_X>
  <CX_DOT_Y>0.306</CX_DOT_Y>
  <CX_DOT_Z>0.276</CX_DOT_Z>
  <CX_DOT_X_DOT>0.797</CX_DOT_X_DOT>
  <CY_DOT_X>0.562</CY_DOT_X>
  <CY_DOT_Y>0.899</CY_DOT_Y>
  <CY_DOT_Z>0.022</CY_DOT_Z>
  <CY_DOT_X_DOT>0.079</CY_DOT_X_DOT>
  <CY_DOT_Y_DOT>0.415</CY_DOT_Y_DOT>
  <CZ_DOT_X>0.245</CZ_DOT_X>
  <CZ_DOT_Y>0.965</CZ_DOT_Y>
  <CZ_DOT_Z>0.950</CZ_DOT_Z>
  <CZ_DOT_X_DOT>0.435</CZ_DOT_X_DOT>
  <CZ_DOT_Y_DOT>0.621</CZ_DOT_Y_DOT>
  <CZ_DOT_Z_DOT>0.991</CZ_DOT_Z_DOT>
</covarianceMatrix>
</data>
</segment>
</body>
</opm>
```

Figure B-6: Sample NDM/XML OPM (continued)

B7 SAMPLE QUALIFIED NDM/XML INSTANCE

The following is a simple sample of a qualified NDM/XML instance:

```
<?xml version="1.0" encoding="UTF-8"?>
<ndm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:ndm="urn:ccsds:schema:ndmxml"
  xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml_qualified/ndmxml-2.0.0-
master-2.0.xsd">
<ndm:opm id="CCSDS_OPM_VERS" version="2.0">
  <ndm:header>
    <ndm:COMMENT>In this simple case, there are no Keplerian elements, no maneuver, no S/C
parameters, no covariance matrix; this is essentially just the state vector</ndm:COMMENT>
    <ndm:CREATION_DATE>2009-05-18T13:06:00</ndm:CREATION_DATE>
    <ndm:ORIGINATOR>GSFC</ndm:ORIGINATOR>
  </ndm:header>
  <ndm:body>
    <ndm:segment>
      <ndm:metadata>
        <ndm:OBJECT_NAME>SOHO</ndm:OBJECT_NAME>
        <ndm:OBJECT_ID>2009-000A</ndm:OBJECT_ID>
        <ndm:CENTER_NAME>EARTH</ndm:CENTER_NAME>
        <ndm:REF_FRAME>EME2000</ndm:REF_FRAME>
        <ndm:TIME_SYSTEM>UTC</ndm:TIME_SYSTEM>
      </ndm:metadata>
      <ndm:data>
        <ndm:stateVector>
          <ndm:EPOCH>2009-04-28T00:00:00</ndm:EPOCH>
          <ndm:X>0.11480770338073E+07</ndm:X>
          <ndm:Y>0.50826618901580E+06</ndm:Y>
          <ndm:Z>0.32422917889939E+06</ndm:Z>
          <ndm:X_DOT>-0.29736064079430</ndm:X_DOT>
          <ndm:Y_DOT>0.39070228393147</ndm:Y_DOT>
          <ndm:Z_DOT>0.19156258887615</ndm:Z_DOT>
        </ndm:stateVector>
      </ndm:data>
    </ndm:segment>
  </ndm:body>
</ndm:opm>
<ndm:opm id="CCSDS_OPM_VERS" version="2.0">
  <ndm:header>
    <ndm:CREATION_DATE>2009-05-18T13:06:00</ndm:CREATION_DATE>
    <ndm:ORIGINATOR>GSFC</ndm:ORIGINATOR>
  </ndm:header>
  <ndm:body>
    <ndm:segment>
      <ndm:metadata>
        <ndm:OBJECT_NAME>SOHO</ndm:OBJECT_NAME>
        <ndm:OBJECT_ID>2009-000A</ndm:OBJECT_ID>
        <ndm:CENTER_NAME>EARTH</ndm:CENTER_NAME>
        <ndm:REF_FRAME>EME2000</ndm:REF_FRAME>
        <ndm:TIME_SYSTEM>UTC</ndm:TIME_SYSTEM>
      </ndm:metadata>
      <ndm:data>
        <ndm:stateVector>
          <ndm:EPOCH>2009-04-28T00:00:00</ndm:EPOCH>
          <ndm:X>0.11480770338073E+07</ndm:X>
          <ndm:Y>0.50826618901580E+06</ndm:Y>
          <ndm:Z>0.32422917889939E+06</ndm:Z>
          <ndm:X_DOT>-0.29736064079430</ndm:X_DOT>
          <ndm:Y_DOT>0.39070228393147</ndm:Y_DOT>
          <ndm:Z_DOT>0.19156258887615</ndm:Z_DOT>
        </ndm:stateVector>
      </ndm:data>
    </ndm:segment>
  </ndm:body>
</ndm:opm>
</ndm>
```

Figure B-7: Sample Combined Instantiation with elementFormDefault="qualified"

ANNEX C

INFORMATIVE REFERENCES

(INFORMATIVE)

- [C1] *Navigation Data—Definitions and Conventions*. Issue 4. Report Concerning Space Data System Standards (Green Book), CCSDS 500.0-G-4. Washington, D.C.: CCSDS, November 2019.
- [C2] Fran Martínez. “XML in CCSDS.” Presented at CCSDS Navigation Working Group meeting (May 2004, Montreal). <https://cwe.ccsds.org/moims/docs/MOIMS-NAV/NDM%20XML%20Related%20Material/XML-in-CCSDS-Montreal-2004.ppt>.
- [C3] *Space Communication Cross Support—Service Management—Service Specification*. Issue 1-S. Recommendation for Space Data System Standards (Historical), CCSDS 910.11-B-1-S. Washington, D.C.: CCSDS, (August 2009) June 2017.
- [C4] *Information Technology—8-Bit Single-Byte Coded Graphic Character Sets—Part 1: Latin Alphabet No. 1*. International Standard, ISO/IEC 8859-1:1998. Geneva: ISO, 1998.
- [C5] "SourceForge.net: XMill." SourceForge.net: Open Source Software. <https://sourceforge.net/projects/xmill>.
- [C6] "SourceForge.net: XGrind: A Query-Friendly XML Compressor." SourceForge.net: Open Source Software. <https://sourceforge.net/projects/xgrind/>.
- [C7] RELAX NG home page. <https://relaxng.org/>.
- [C8] *Information Technology—Document Schema Definition Languages (DSDL)—Part 3: Rule-Based Validation—Schematron*. 3rd ed. International Standard, ISO/IEC 19757-3:2020. Geneva: ISO, 2020.

NOTE – Normative references appear in 1.6.

ANNEX D

RATIONALE FOR XML-FORMAT NAVIGATION DATA MESSAGES

(INFORMATIVE)

D1 GENERAL

This annex presents the rationale behind the design of the NDM XML Specification. It is intended to help the application engineer construct a suitable valid message. Corrections and/or additions to these requirements during future updates are possible.

A specification of requirements agreed to by all parties is essential to focus design and to ensure the product meets the needs of the Member Agencies. There are many ways of organizing requirements, but the categorization of requirements is not as important as the agreement to a sufficiently comprehensive set. In this annex, the requirements are organized into three categories:

Primary Requirements are the most elementary and necessary requirements. They would exist no matter the context in which the CCSDS is operating, that is, regardless of pre-existing conditions within the CCSDS or its Member Agencies.

Heritage Requirements are additional requirements that derive from pre-existing Member Agency requirements, conditions or needs. Ultimately these carry the same weight as the Primary Requirements. This Recommended Standard reflects heritage requirements pertaining to some of the technical participants' home institutions collected during the preparation of the Recommended Standard; it does not speculate on heritage requirements that could arise from other Member Agencies.

Desirable Characteristics are not requirements, but they are felt to be important or useful features of the Recommended Standard.

D2 PRIMARY REQUIREMENTS ACCEPTED FOR XML-FORMAT NAVIGATION DATA MESSAGES

Table D-1: Primary Requirements

ID	Requirement
D-1-1	The NDM/XML data must be provided in digital form (computer file).
D-1-2	The NDM/XML shall be represented by a valid XML format descriptor.
D-1-3	The NDM/XML format descriptor shall be hosted on the SANA Registry, whence it can be shared by all agencies exchanging instantiations of the format descriptor.
D-1-4	The NDM/XML shall allow for the representation of all the fields available in the Navigation Data Messages Recommended Standards. ³
D-1-5	Files must be readily portable between and useable within 'all' computational environments in use by Member Agencies choosing to exchange NDMs via XML.
D-1-86	Files must have means of being uniquely identified and clearly annotated. The file name alone is considered insufficient for this purpose.
D-1-7	File name syntax and length must not violate computer constraints for those computing environments in use by Member Agencies.
D-1-8	The NDM/XML shall use XML elements when there is substructure associated with information, for example, maneuver parameters.
D-1-9	The NDM/XML shall use XML elements when there is data type checking associated with information, for example, maneuver parameters.

Table D-2: Heritage Requirements

<u>ID</u>	<u>Requirement</u>
D-2-1	The standard shall be, or must include, an ASCII format.
D-2-2	The standard shall not require software supplied by other agencies to process valid instantiations of the NDM/XML schema.

Table D-3: Desirable Characteristics

<u>ID</u>	<u>Requirement</u>
D-3-1	The standard should be extensible with no disruption to existing users/uses.
D-3-2	Keywords, values, and terminology in the NDM/XML should be the same as those in the Navigation Data Messages Recommended Standards, ⁴ insofar as it is possible.

³ These are the references listed in references [4]–[8].

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

<u>ID</u>	<u>Requirement</u>
D-3-3	Structures in the NDM/XML should be re-used across the different message types when practical.
D-3-4	The NDM/XML should minimize the use of tags that do not correspond to keywords in the Navigation Data Messages Recommended Standards. ⁴
D-3-5	Units may be specified in the NDM/XML instantiations. The standard should provide for clear specification of units of measure.
D-3-6	The NDM/XML may use XML attributes when there is no substructure associated with information (e.g., units specifications).

⁴ These are the references listed in references [4]–[8].

ANNEX E**ABBREVIATIONS AND ACRONYMS****(INFORMATIVE)**

ADM	Attitude Data Messages
AEM	Attitude Ephemeris Message
aem	Attitude Ephemeris Message tag
APM	Attitude Parameter Message
apm	Attitude Parameter Message tag
ASCII	American Standard Code for Information Interchange
CCSDS	Consultative Committee on Space Data Systems
CDM	Conjunction Data Message
cdm	Conjunction Data Message tag
CMC	CCSDS Management Council
CWE	Collaborative Working Environment
DTD	Document Type Definition
HTML	HyperText Markup Language
ICD	Interface Control Document
ICS	Implementation Conformance Statement
ISO	International Organization for Standardization
KVN	Keyword Value notation
MOIMS	Mission Operations and Information Management Services
NDM	Navigation Data Message
ndm	Navigation Data Message tag
NDM/XML	Navigation Data Messages XML Specification
ODM	Orbit Data Messages
OEM	Orbit Ephemeris Message
oem	Orbit Ephemeris Message tag
OMM	Orbit Mean Elements Message
omm	Orbit Mean Elements Message tag
OPM	Orbit Parameter Message
opm	Orbit Parameter Message tag
PVL	Parameter Value Language
RDM	Re-entry Data Message

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

rdm	Re-entry Data Message tag
SANA	Space Assigned Numbers Authority
SFTP	Secure File Transfer Protocol
SIG	Special Interest Group
TDM	Tracking Data Message
tdm	Tracking Data Message tag
URL	Uniform Resource Locator
W3C	World Wide Web Consortium
XML	Extensible Markup Language
XSD	XML Schema Definition
XTCE	XML Telemetry and Command Exchange

ANNEX F

CHANGES IN NDM/XML VERSION 2

(INFORMATIVE)

Accommodation for ‘elementFormDefault="qualified"’ schemas has been added (Version 1 only dealt with ‘elementFormDefault="unqualified"’ schemas). This allows the NDM/XML schemas to be included in other schemas without causing namespace collisions, thus providing broader utility.

Material related to the TDM has been removed. It is now described in the TDM Version 2.

Support for the ODM Version 1 has been removed; it has been in Silver Book status for over 10 years. This reduces the overall schema complexity. (Note: Older versions will still be available by special request for those who need them.)

The two ‘common’ schemas employed in NDM/XML Version 1 have been consolidated into one (specifically, the ‘ccsds common’ and ‘navwg common’ have been merged into a new ‘ndm common’ schema). The originally anticipated need for the ccsds common schema has never materialized in over 15 years. Combining the two schemas into one reduces overall schema complexity.

The namespace structure has been revised. It now conforms to the CCSDS XML Special Interest Group (SIG) revised namespace structure set in approximately 2013; the namespace structure used in NDM/XML Version 1 conforms to the XML/SIG’s original namespace structure set in approximately 2007.