The Consultative Committee for Space Data Systems

Draft Recommendation for
Space Data System Standards

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

DRAFT RECOMMENDED STANDARD

CCSDS 505.0-P-3.1

PINK SHEETS
May 2024

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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505.0-B-1	XML Specification for Navigation Data Messages, Recommended Standard, Issue 1	December 2010	Original issue, superseded
CCSDS 505.0-B-2	XML Specification for Navigation Data Messages, Recommended Standard, Issue 2	May 2021	Issue 2, superseded
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NOTE – Changes from the current issue are summarized in annex J. Only pages containing changes are included in this review document.

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, the TDM version 2 in 2020, and the ODM version 3 in 2023). As the early Navigation Working Group Recommended Standards ~~are~~were being revised, the strategy ~~is~~has been to remove the XML formatting discussion from this NDM/XML document and migrate it into the revised documents; the ADM is the last of ~~these~~the early Navigation Working Group early standards. (It should be noted that the CCSDS Pointing Request Message [PRM] is also a standard created by the CCSDS Navigation Working Group, but it is implemented using a set of XML templates rather than as an XML message that can be validated via the XML schema language.)

The first version of this document only encompassed schemas and messages in which the XML 'elementFormDefault="unqualified"' applied. This version of the Recommended Standard encompasses schemas and messages in which the XML 'elementFormDefault="unqualified"' and 'elementFormDefault="qualified"' both apply. The "qualified" schemas 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 E 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 XML instantiations of ~~the ADM~~these message types ~~and 'combined instantiations'~~ are provided in references [4]–[8]. Instructions for providing 'mixed combined instantiations' consisting of messages from multiple Navigation Working Group standards are provided in this section.

Annex A explains why this document does not contain an Implementation Conformance Statement (ICS), a component of typical CCSDS Recommended Standards.

Annex B explains why this document does not provide in annex B the material that is provided in annex B of other Navigation Working Group standards.

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

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

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). https://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. https://www.w3.org/TR/2004/REC-xmlschema-2-20041028/.

[3] "Navigation Data Messages XML Schema." Space Assigned Numbers Authority. https://nav.sanaregistry.org/r/ndmxml.

[4] *Attitude Data Messages*. Issue ~~1~~2. Recommendation for Space Data System Standards (Blue Book), CCSDS 504.0-B-~~1~~2. Washington, D.C.: CCSDS, ~~May 2008~~January 2024.

[5] *Orbit Data Messages*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 502.0-B-3. Washington, D.C.: CCSDS, April 2023.

[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 H.

2 OVERVIEW

2.1 NAVIGATION DATA MESSAGES

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.

2.2 ATTITUDE DATA MESSAGES

Attitude Data Messages comprise ~~two~~three message types used to convey spacecraft attitude information: the Attitude Parameter Message (APM), ~~and~~the Attitude Ephemeris Message (AEM), and the Attitude Comprehensive Message (ACM). 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. ~~Instructions for creating an XML instantiation of the messages in the ADM are specified in section 4 of this document. The APM and AEM are specified in reference [4]~~The ACM aggregates and extends APM and AEM content in a single comprehensive hybrid message and includes a great deal of additional information about the spacecraft and its environment. Instructions for creating an XML instantiation of the messages in the ADM version 2 are contained in the ADM document itself (reference [4]).

2.3 ORBIT DATA MESSAGES

Orbit Data Messages comprise four message types used to convey trajectory information: the Orbit Parameter Message (OPM), Orbit Mean Elements Message (OMM), Orbit Ephemeris Message (OEM), and Orbit Comprehensive Message (OCM). 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 OCM aggregates and extends OPM, OMM, and OEM content in a single comprehensive hybrid message and includes a great deal of additional information about the spacecraft and its environment. Instructions for creating an XML instantiation of the messages in the ODM version 3 are contained in the ODM document itself~~. The OPM, OMM, OEM, and OCM are specified in~~ (reference [5]).

2.4 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 XML instantiation of the TDM version 2 are contained in the TDM document itself~~. The TDM is specified in~~ (reference [6]).

2.5 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 XML instantiation of the CDM are contained in the CDM document itself~~. The CDM is specified in~~ (reference [7]).

2.6 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 XML instantiation of the RDM are contained in the RDM document itself~~. The RDM is specified in~~ (reference [8]).

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 issue[1] of each individual message type (see references [4]–[8]), an 'NDM combined instantiation' schema (see 4.9), 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://nav.sanaregistry.org/r/ndmxml for links to the two schema subsets below:

  • https://nav.sanaregistry.org/r/ndmxml_unqualified/[schemaName] for schemas with the attribute 'elementFormDefault="unqualified"';

  • https://nav.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~~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~~x' is a schema revision indicator ('0' for the initial version, then {'A', 'B', 'C',...} for successive revisions (see the SANA Registry for the current NDM/XML version number);

– [messageType] is one of the individual message types described in references [4]–[8] (e.g., APM, CDM, OPM, RDM, TDM, etc.);

– [blueBookNumber] is the most current Blue Book version corresponding to the message ~~(e.g., '1.0' for the AEM and APM)~~(e.g., '2.0' for the AEM, APM, and ACM).

[1] 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~~Table 3-1 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 this 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"'.

5 Past versions of the NDM/XML Schema Set in tar file format are available at https://cwe.ccsds.org/moims/docs/MOIMS-NAV/NDM-XML-Schema-Archive/past-ndmxml-releases.html

Table 3-1: The NDM/XML Schema Set

Schema	Blue Book Supported	Root Tag
ndmxml-4.0.x-acm-2.0.xsd	ADM Attitude Comprehensive Message (reference [4])	<acm>
ndmxml-~~3~~4.0.x-aem-~~1~~2.0.xsd~~*~~	ADM Attitude Ephemeris Message (reference [4])	<aem>
ndmxml-~~3~~4.0.x-apm-~~1~~2.0.xsd~~*~~	ADM Attitude Parameter Message (reference [4])	<apm>
ndmxml-~~3~~4.0.x-cdm-1.0.xsd	CDM Conjunction Data Message (reference [7])	<cdm>
ndmxml-~~3~~4.0.x-common-3.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-~~3~~4.0.x-master-3.n.xsd	NDM/XML master schema, used to validate all instantiations, import the NDM/XML namespace, and declare all schema set root elements. Supports all references listed in references [4]–[8].	N/A
ndmxml-~~3~~4.0.x-namespace-3.n.xsd	Includes each element of the NDM/XML schema set. Supports all references listed in references [4]–[8].	N/A
ndmxml-~~3~~4.0.x-ndm-3.0.xsd	NDM combined instantiation schema (see 4.9)	<ndm>
ndmxml-~~3~~4.0.x-ocm-3.0.xsd	ODM Orbit Comprehensive Message (reference [5])	<ocm>
ndmxml-~~3~~4.0.x-oem-3.0.xsd	ODM Orbit Ephemeris Message (reference [5])	<oem>

Schema	Blue Book Supported	Root Tag
ndmxml-~~3~~4.0.x-omm-3.0.xsd	ODM Orbit Mean Elements Message (reference [5])	<omm>
ndmxml-~~3~~4.0.x-opm-3.0.xsd	ODM Orbit Parameter Message (reference [5])	<opm>
ndmxml-~~3~~4.0.x-rdm-1.0.xsd	RDM Re-entry Data Message (reference [8])	<rdm>
ndmxml-~~3~~4.0.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: ACM, APM, OCM, OMM, OPM, RDM

The body of several NDMs (~~e.g.~~ACM, APM, OCM, OMM, OPM, and RDM) shall consist of a single segment, as shown in figure 3-1. Generally these NDMs describe a single state; the OCM ~~varies~~and ACM vary from this pattern.

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.

```
<header>
</header>
<body>
  &lt;segment&gt;
     <metadata>
     </metadata>
     <data>
     </data>
  &lt;/segment&gt;
</body>
```

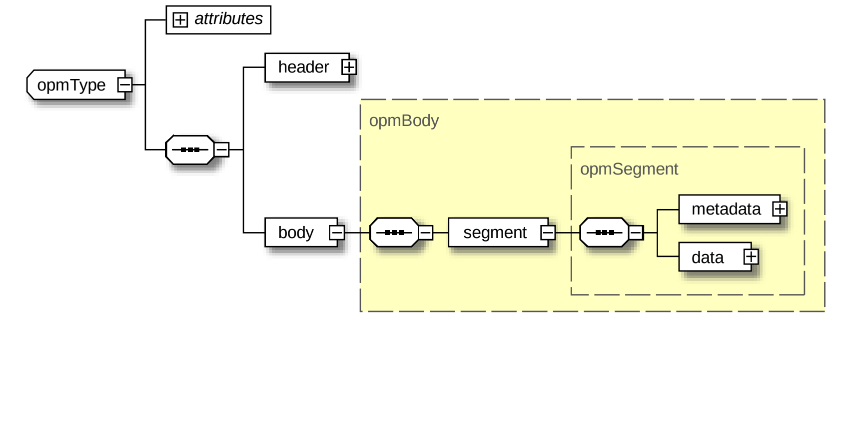

Figure 3-1: NDM/XML Substructure 1 (Single Segment)

3.4 SUBSTRUCTURE 2: AEM, OEM, TDM, AND CDM

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

3.4.2 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).

NOTE – The alternation of associated metadata and data sections is the structural element that necessitates the notion of the segment.

<header>
</header>
<body>
  <relativeMetadata>
  </relativeMetadata>
  <segment>
    <metadata>
    </metadata>
    <data>
    </data>
  </segment>
  <segment>
    <metadata>
    </metadata>
    <data>
    </data>
  </segment>
</body>

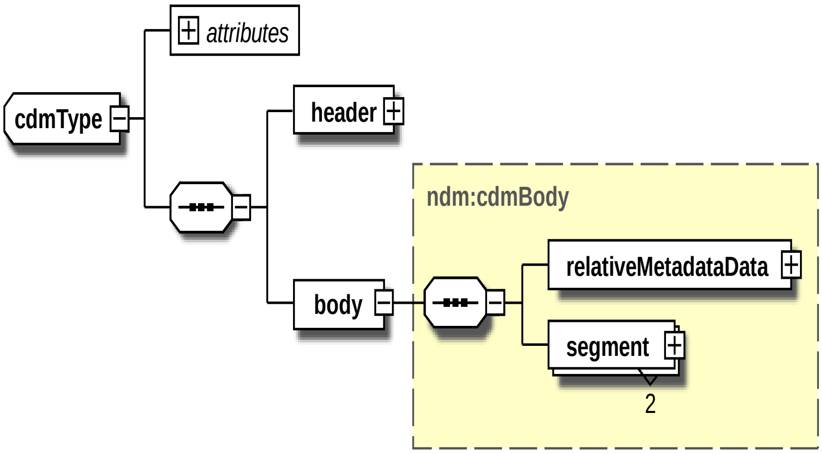

Figure 3-3: Variant of Substructure 2 for CDM

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.

NOTE – There are ~~three~~two exceptions for 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~~

b) keywords associated with user-defined parameters in some of the documents (see 4.8).

In the first ~~two exceptions~~exception, the KVN keywords appear as XML attributes rather than as XML elements. In the ~~last~~second 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. The use of <userDefinedParameters> is defined in 4.8.

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]. ~~In particular, with the current exception of the Attitude Data Messages (reference [4]), the instructions for creating XML formatted messages are described in references [5]–[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"
```

NOTE – 'https:' is not a valid value in the above string, as it is the name of a namespace, not the name of an internet protocol.

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://nav.sanaregistry.org/r/ndmxml_unqualified/ndmxml-~~3~~4.0.X-master-~~3~~4.0.xsd"` (if `'elementFormDefault="unqualified"'` is desired)

`xsi:noNamespaceSchemaLocation="https://nav.sanaregistry.org/r/ndmxml_qualified/ndmxml-~~3~~4.0.X-master-~~3~~4.0.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 '~~3~~4.0.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., ~~3~~4.0.0 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 issue 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 issue 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="https://nav.sanaregistry.org/r/ndmxml_unqualified
          /ndmxml-3.0.0-master-3.0.xsd"
      id="CCSDS_OPM_VERS" version="3.0">

<?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="https://nav.sanaregistry.org/r/ndmxml_qualified/ndmx
ml-3.0.0-master-3.0.xsd"
      id="CCSDS_OPM_VERS" version="3.0">
```

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 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].

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 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 G-1 and G-2 in annex G 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.~~

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

~~**4.8.1.7** Each 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

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

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 <rotation*i*> (*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 G-3 in annex G 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.

4.9.6 The APM <body> shall consist of a single (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 specifies 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 <eulerElementsThree>
<eulerElementsThree>, after the <RATE_FRAME> tag	<rotationAngles> <rotationRates>

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 <rotation*i*> (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 <rotationi> 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>
```

4.8 USER DEFINED PARAMETERS

4.8.1 BACKGROUND

~~NOTE –~~ User-defined parameters have been added to some of the Navigation Data Messages (e.g., OPM, OMM, OCM (reference [5]); and RDM (reference [8]). As other Navigation Data Message standards are updated, it is likely that the ability to include user-defined parameters will be added to them. 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>.

```
<ndm>
<COMMENT>Generally,
at least one AEM,
APM, CDM, OCM, OEM,
OMM, OPM, RDM, or
TDM. Constituent
messages can occur
in any quantity (0
or more) or
order.</COMMENT>
      <acm>
      </acm>
      <aem>
      </aem>
      <apm>
      </apm>
      <cdm>
      </cdm>
      <ocm>
      </ocm>
      <oem>
      </oem>
      <omm>
      </omm>
      <opm>
      </opm>
      <rdm>
      </rdm>
      <tdm>
      </tdm>
</ndm>
```

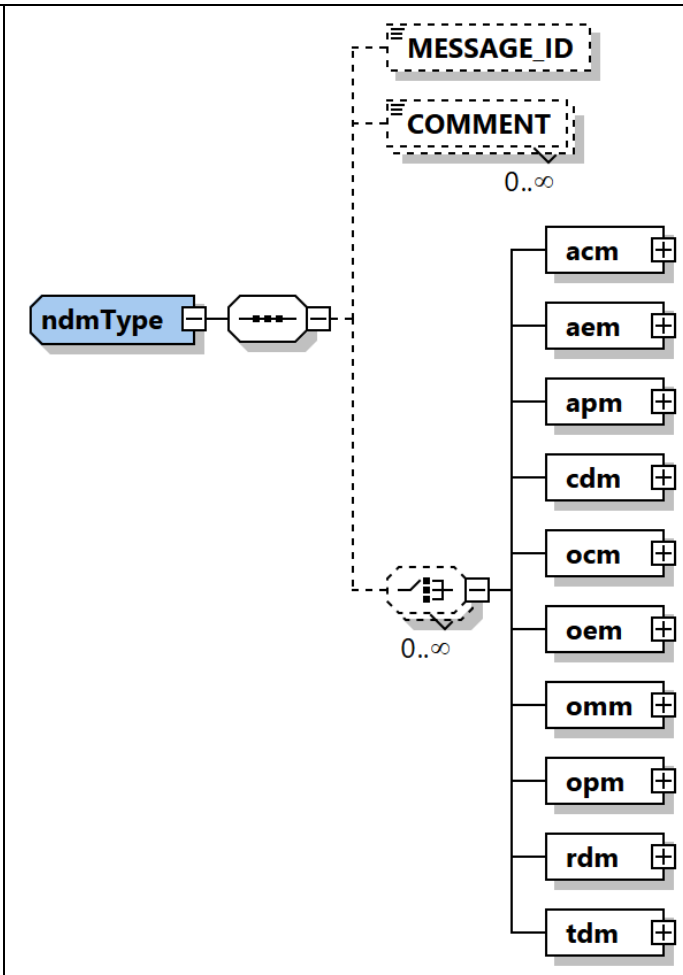

Figure 4-2: NDM Combined Instantiation Basic Structure

```
<?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="https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-34.0.0-
master-34.0.xsd">
   <apm id="CCSDS_APM_VERS" version="12.0">
      <header>
      </header>
      <body>
      </body>
   </apm>
   <aem id="CCSDS_AEM_VERS" version="12.0">
      <header>
      </header>
      <body>
      </body>
   </aem>
   <acm id="CCSDS_ACM_VERS" version="2.0">
      <header>
      </header>
      <body>
      </body>
   </acm>
   <cdm id="CCSDS_CDM_VERS" version="1.0">
      <header>
      </header>
      <body>
      </body>
   </cdm>
   <opm id="CCSDS_OPM_VERS" version="3.0">
      <header>
      </header>
      <body>
      </body>
   </opm>
   <omm id="CCSDS_OMM_VERS" version="3.0">
      <header>
      </header>
      <body>
      </body>
   </omm>
   <oem id="CCSDS_OEM_VERS" version="3.0">
      <header>
      </header>
      <body>
      </body>
   </oem>
   <ocm id="CCSDS_OCM_VERS" version="3.0">
      <header>
      </header>
      <body>
      </body>
   </ocm>
   <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 D

ABBREVIATIONS AND ACRONYMS

(INFORMATIVE)

ACM	Attitude Comprehensive Message
acm	Attitude Comprehensive Message tag
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
OCM	Orbit Comprehensive Message
ocm	Orbit Comprehensive Message tag
ODM	Orbit Data Messages
OEM	Orbit Ephemeris Message
oem	Orbit Ephemeris Message tag
OMM	Orbit Mean Elements Message
omm	Orbit Mean Elements Message tag

~~G2 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="https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-3.0.0-
master-3.0.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</ORIGINATOR>
   </header>
   <body>
      &lt;segment&gt;
         <metadata>
            <COMMENT>This file was produced by M.R. Somebody, MSOO NAV, 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>
```

~~Figure G-1: Sample NDM/XML AEM~~

```
            <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>
      &lt;/segment&gt;
   </body>
</aem>
```

~~**Figure G-1: Sample NDM/XML AEM (continued)**~~

```
<?xml version="1.0" encoding="UTF-8"?>
<aem  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:noNamespaceSchemaLocation="https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-3.0.0-master-3.0.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>
      &lt;segment&gt;
         <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>
      &lt;/segment&gt;
   </body>
</aem>
```


~~Figure G-2: Sample NDM/XML AEM with Rotation~~

~~G3 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="https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-3.0.0-master-3.0.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>NASA</ORIGINATOR>
   </header>
   <body>
      &lt;segment&gt;
         <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 NASA</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_1</Q_FRAME_A>
               <Q_FRAME_B>ITRF1997</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_1</EULER_FRAME_A>
               <EULER_FRAME_B>ITRF1997</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>
```


~~Figure G-3: Sample NDM/XML APM~~

```
            </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_1</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>
      &lt;/segment&gt;
   </body>
</apm>
```

~~**Figure G-3: Sample NDM/XML APM (continued)**~~

G2 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="https://nav.sanaregistry.org/r/ndmxml_qualified/ndmxml-34.0.0-master-34.0.xsd">
<ndm:opm      id="CCSDS_OPM_VERS" version="3.0">
   <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="3.0">
   <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 G-1: Sample Combined Instantiation with elementFormDefault="qualified"

G3 SAMPLE UNQUALIFIED NDM/XML INSTANCE


```xml
<?xml version="1.0" encoding="UTF-8"?>
<apm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xsi:noNamespaceSchemaLocation="https://nav.sanaregistry.org/r/ndmxml_unqualified/ndmxml-
4.0.0-master-4.0.xsd"
     xmlns:ndm="urn:ccsds:schema:ndmxml"
     id="CCSDS_APM_VERS" version="2.0">

   <header>
      <CREATION_DATE>2023-01-21T11:55:00</CREATION_DATE>
      <ORIGINATOR>GSFC</ORIGINATOR>
      <MESSAGE_ID>A000001</MESSAGE_ID>
   </header>
   <body>
      &lt;segment&gt;
         <metadata>
            <COMMENT>SPINNING</COMMENT>
            <OBJECT_NAME>MMS1</OBJECT_NAME>
            <OBJECT_ID>2015-011A</OBJECT_ID>
            <CENTER_NAME>EARTH</CENTER_NAME>
            <TIME_SYSTEM>TAI</TIME_SYSTEM>
         </metadata>
         <data>
            <COMMENT>Current Attitude</COMMENT>
            <COMMENT>Spin Parameters</COMMENT>
            <EPOCH>2023-01-01T00:00:00.0000</EPOCH>
            <spin>
               <REF_FRAME_A>J2000</REF_FRAME_A>
               <REF_FRAME_B>SC_BODY1</REF_FRAME_B>
               <SPIN_ALPHA units="deg">10</SPIN_ALPHA>
               <SPIN_DELTA units="deg">30</SPIN_DELTA>
               <SPIN_ANGLE units="deg">0</SPIN_ANGLE>
               <SPIN_ANGLE_VEL units="deg/s">1</SPIN_ANGLE_VEL>
               <MOMENTUM_ALPHA units="deg">80</MOMENTUM_ALPHA>
               <MOMENTUM_DELTA units="deg">10</MOMENTUM_DELTA>
               <NUTATION_VEL units="deg/s">0.5</NUTATION_VEL>
            </spin>
         </data>
      &lt;/segment&gt;
   </body>
</apm>
```


Figure G-2: Sample Combined Instantiation with elementFormDefault="unqualified"

ANNEX J

CHANGES IN NDM/XML VERSION ~~3~~4

(INFORMATIVE)

~~J1~~ Detailed material related to creating XML instantiations of the ~~Orbit~~Attitude Data Messages (~~ODM~~ADM) has been removed. This material is now described in the ~~ODM~~ADM version ~~3~~2, reference ~~[5]~~[4].

~~J2 The document annexes have been rearranged relative to the previous version to conform to a guideline developed for all of the CCSDS Navigation Working Group documents.~~