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Space data and information transfer systems — XML specification for navigation data messages

Systèmes de transfert des informations et données spatiales — Spécifications XML pour les messages de données de navigation

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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ISO 17107 was prepared by the Consultative Committee for Space Data Systems (CCSDS) as CCSDS 505.0-B-1, December 2010 and was adopted without modifications except those stated in Clause 2 of this International Standard by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 13, *Space data and information transfer systems*.

Space data and information transfer systems — XML specification for navigation data messages

1 Scope

This International Standard specifies a format for use in exchanging spacecraft navigation data. Such exchanges are used for distributing attitude, orbit, and tracking data between space agencies. This International Standard specifies an integrated Extensible Markup Language (XML) schema set that applies to Navigation Data Messages (NDMs) defined in the CCSDS Recommended Standards for Attitude Data Messages (ADM), Orbit Data Messages (ODM), and Tracking Data Message (TDM).

This XML schema set is suited to inter-agency exchanges of any number of NDMs (ADM, ODM, and/or TDM).

This International 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 potential for compression/decompression of the message is an aspect of the transmission that is not part of this specification. The means of transmission of an XML-formatted NDM between agencies is beyond the scope of this International Standard; such arrangements require specification via other means, for example, in an Interface Control Document (ICD).

The scope and field of application are furthermore detailed in subclauses 1.2 to 1.4 of the enclosed CCSDS publication.

2 Requirements

Requirements are the technical recommendations made in the following publication (reproduced on the following pages), which is adopted as an International Standard:

CCSDS 505.0-B-1, December 2010, *XML Specification for Navigation Data Messages*.

For the purposes of international standardization, the modifications outlined below shall apply to the specific clauses and paragraphs of publication CCSDS 505.0-B-1.

Pages i to vi

This part is information which is relevant to the CCSDS publication only.

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Add the following information to the reference indicated:

[1] Document CCSDS 504.0-B-1, May 2008, is equivalent to ISO 13541:2010.

[2] Document CCSDS 502.0-B-2, November 2009, is equivalent to ISO 26900:—[1)].

[3] Document CCSDS 503.0-B-1, November 2007, is equivalent to ISO 13526:2010.

1) To be published.

3 Revision of publication CCSDS 505.0-B-1

It has been agreed with the Consultative Committee for Space Data Systems that Subcommittee ISO/TC 20/SC 13 will be consulted in the event of any revision or amendment of publication CCSDS 505.0-B-1. To this end, NASA will act as a liaison body between CCSDS and ISO.

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-1

BLUE BOOK

December 2010

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XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

AUTHORITY

Issue:	Recommended Standard, Issue 1
Date:	December 2010
Location:	Washington, DC, USA

This document has been approved for publication by the Management Council of the Consultative Committee for Space Data Systems (CCSDS) and represents the consensus technical agreement of the participating CCSDS Member Agencies. The procedure for review and authorization of CCSDS documents is detailed in the *Procedures Manual for the Consultative Committee for Space Data Systems*, and the record of Agency participation in the authorization of this document can be obtained from the CCSDS Secretariat at the address below.

This document is published and maintained by:

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STATEMENT OF INTENT

The Consultative Committee for Space Data Systems (CCSDS) is an organization officially established by the management of its members. The Committee meets periodically to address data systems problems that are common to all participants, and to formulate sound technical solutions to these problems. Inasmuch as participation in the CCSDS is completely voluntary, the results of Committee actions are termed **Recommended Standards** and are not considered binding on any Agency.

This **Recommended Standard** is issued by, and represents the consensus of, the CCSDS members. Endorsement of this **Recommendation** is entirely voluntary. Endorsement, however, indicates the following understandings:

- Whenever a member establishes a CCSDS-related **standard**, this **standard** will be in accord with the relevant **Recommended Standard**. Establishing such a **standard** does not preclude other provisions which a member may develop.
- Whenever a member establishes a CCSDS-related **standard**, that member will provide other CCSDS members with the following information:
  - -- The **standard** itself.
  - -- The anticipated date of initial operational capability.
  - -- The anticipated duration of operational service.
- Specific service arrangements shall be made via memoranda of agreement. Neither this **Recommended Standard** nor any ensuing **standard** is a substitute for a memorandum of agreement.

No later than five years from its date of issuance, this **Recommended Standard** will be reviewed by the CCSDS to determine whether it should: (1) remain in effect without change; (2) be changed to reflect the impact of new technologies, new requirements, or new directions; or (3) be retired or canceled.

In those instances when a new version of a **Recommended Standard** is issued, existing CCSDS-related member standards and implementations are not negated or deemed to be non-CCSDS compatible. It is the responsibility of each member to determine when such standards or implementations are to be modified. Each member is, however, strongly encouraged to direct planning for its new standards and implementations towards the later version of the Recommended Standard.

FOREWORD

This document is a technical Recommended Standard for an XML Specification for Navigation Data Messages (Orbit Data Messages, Attitude Data Messages, Tracking 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.

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, which are defined in the *Procedures Manual for the Consultative Committee for Space Data Systems*. Current versions of CCSDS documents are maintained at the CCSDS Web site:

http://www.ccsds.org/

Questions relating to the contents or status of this document should be addressed to the CCSDS Secretariat at the address indicated on page i.

At time of publication, the active Member and Observer Agencies of the CCSDS were:

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- Agenzia Spaziale Italiana (ASI)/Italy.
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- Naval Center for Space Technology (NCST)/USA.
- Scientific and Technological Research Council of Turkey (TUBITAK)/Turkey.
- Space and Upper Atmosphere Research Commission (SUPARCO)/Pakistan.
- Swedish Space Corporation (SSC)/Sweden.

– 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	Current issue

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

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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 attitude, orbit, and tracking data between space agencies. 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 for *Attitude Data Messages* (ADM, reference [1]), *Orbit Data Messages* (ODM, reference [2]), and *Tracking Data Message* (TDM, reference [3]).

This XML schema set is suited to inter-agency exchanges of any number of NDMs (ADM, ODM, and/or TDM).

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 potential for compression/decompression of the message is an aspect of the transmission that is not part of this specification. The means of transmission of an XML-formatted NDM between agencies 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 SFTP, streaming media, email, or services provided via the World Wide Web and XML-compatible Web browsers. In general, it is a requirement that the transmission mechanism not place constraints on the technical data content of an NDM.

1.3 RATIONALE

This document responds to a requirement levied by the CCSDS to produce an XML format for NDMs. 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., ADM, ODM, and TDM). 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 [1], [2], and [3]. Instructions for how to construct instantiations of the various message types are provided.

Annex A discusses information security considerations.

Annex B provides instructions on where to find the schema set referenced in this 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.

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] *Attitude Data Messages*. Recommendation for Space Data System Standards, CCSDS 504.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, May 2008.

[2] *Orbit Data Messages*. Recommendation for Space Data System Standards, CCSDS 502.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, November 2009.

[3] *Tracking Data Message*. Recommendation for Space Data System Standards, CCSDS 503.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, November 2007.

[4] Henry S. Thompson, et al., eds. *XML Schema Part 1: Structures*. 2nd ed. W3C Recommendation. N.p.: W3C, October 2004. <http://www.w3.org/TR/2004/REC-xmlschema-1-20041028/>

[5] Paul V. Biron and Ashok Malhotra, eds. *XML Schema Part 2: Datatypes*. 2nd Edition. W3C Recommendation. N.p.: W3C, October 2004. <http://www.w3.org/TR/2004/REC-xmlschema-2-20041028/>

NOTE – Informative references are provided in annex C.

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2 OVERVIEW

2.1 NAVIGATION DATA MESSAGES

2.1.1 GENERAL

This subsection provides a brief overview of the set of Navigation Data Messages (NDMs). There are three basic types of NDM: Attitude Data Messages (reference [1]), Orbit Data Messages (reference [2]), and the Tracking Data Message (reference [3]). 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 (ADM) 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 [1].

2.1.3 ORBIT DATA MESSAGES

Orbit Data Messages (ODM) 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 [2].

2.1.4 TRACKING DATA MESSAGE

The Tracking Data Message (TDM) 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 the following types:

- ground-based radio metric types:
  - uplink frequencies,

- downlink frequencies,
- range,
- Doppler,
- antenna angles,
- interferometric types;

– spacecraft-to-spacecraft Doppler and range; and

– ancillary information needed to calculate the measurement residuals, such as meteorological data, media delays, and clock parameters.

The TDM is specified in reference [3].

2.2 EXTENSIBLE MARKUP LANGUAGE

2.2.1 GENERAL

This subsection briefly describes the Extensible Markup Language (XML), generalities of the XML schema, and the justification for using XML for NDMs. XML schema structures and data types are specified in references [4] and [5].

2.2.2 XML OVERVIEW

2.2.2.1 During the development of the ODM, it was determined that the specified Keyword Value Notation (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. 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 ASCII text files for the Navigation Data Messages application include:

– XML allows for the definition of the data message in a machine-readable format. The format is basically a template called a 'schema'. This schema can then be referred to in the data file, and it can be used to verify that the data is 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 field.

– 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 that are skilled in XML.

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. 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 the ODM, ADM and TDM Recommended Standards, consistent with the directive of the CMC. These schema representations adopt the standard as approved by the World Wide Web Consortium (W3C) (http://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 six 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 will be stored in the CCSDS Space Assigned Numbers Authority (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 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

[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.

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 elements of the schema set corresponding to the original issue of the ODM restrict the placement of comments.

2.3.2 DISCUSSION OF 'VALIDATION CHECKING'

There are some elements in the ADM, ODM, and TDM 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 ADM, ODM, and TDM, 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).

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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 a Navigation Data Message (NDM). An 'NDM' shall consist of at least one of the following messages:

- Attitude Parameter Message (APM, reference [1], section 3);
- Attitude Ephemeris Message (AEM, reference [1], section 4);
- Orbit Parameter Message (OPM, reference [2], section 3);
- Orbit Mean Elements Message (OMM, reference [2], section 4);
- Orbit Ephemeris Message (OEM, reference [2], section 5);
- Tracking Data Message (TDM, reference [3], section 3).

3.1.2 The NDM/XML schema set shall consist of a schema for each Blue Book version[2] of each individual message type, an 'NDM combined instantiation' schema, a namespace schema, and a master validator schema. A schema containing elements common to more than one Navigation Working Group schema and a schema containing elements that are potentially common across more than one CCSDS application complete the current schema set, yielding a schema set with a total of 11 members (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:

http://sanaregistry.org/r/ndmxml/[schemaName]

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 1.0
- [messageType] is one of the set {aem, apm, oem, omm, opm, tdm}
- [blueBookNumber] is the Blue Book version of the respective 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 also several test files and example NDM/XML instantiations on the CCSDS Web site.

2 The following table illustrates the naming convention in the names of the NDM/XML schema set. The 'Blue Book Supported' column indicates the messages and respective Blue Books to which the schema applies.

3 Special considerations apply to instantiations that are compatible with the ODM Issue 1.0 Silver Book. These are described in the portions of section 4 that address instantiations of the OEM and OPM.

4 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.

Table 3-1: The NDM/XML Schema Set

Schema	Blue Book Supported
ndmxml-1.0-aem-1.0.xsd	ADM Attitude Ephemeris Message (Blue 1.0).
ndmxml-1.0-apm-1.0.xsd	ADM Attitude Parameter Message (Blue 1.0).
ndmxml-1.0-oem-2.0.xsd	ODM Orbit Ephemeris Message (Blue 2.0).
ndmxml-1.0-omm-2.0.xsd	ODM Orbit Mean Elements Message (Blue 2.0).
ndmxml-1.0-opm-2.0.xsd	ODM Orbit Parameter Message (Blue 2.0).
ndmxml-1.0-tdm-1.0.xsd	TDM Tracking Data Message (Blue 1.0).
ndmxml-1.0-navwg-common.xsd	Constructs unique to Navigation Working Group used in more than one schema in the NDM schema set. ADM 1.0, ODM 2.0, TDM 1.0.
ndmxml-1.0-ccsds-common.xsd	Constructs that could in principle be used across the CCSDS domain. ADM 1.0, ODM 2.0, TDM 1.0.
ndmxml-1.0-ndm-1.0.xsd	NDM combined instantiation schema, used where it is desired to exchange multiple related constituent NDMs. ADM 1.0, ODM 2.0, TDM 1.0.
ndmxml-1.0-namespace.xsd	Schema that includes each element of the NDM XML schema set. ADM 1.0, ODM 2.0, TDM 1.0.
ndmxml-1.0-master.xsd	Overall master schema, used to validate all NDM XML instantiations. It imports the NDM XML namespace and declares all of the root elements of the schema set. ADM 1.0, ODM 2.0, TDM 1.0.

3.2 NDM/XML BASIC STRUCTURE

3.2.1 Each constituent NDM (AEM, APM, OEM, OMM, OPM, and TDM) 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 [1], [2], [3]); 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

The body of NDMs that describe a single state (APM, OMM, and OPM) 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.

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

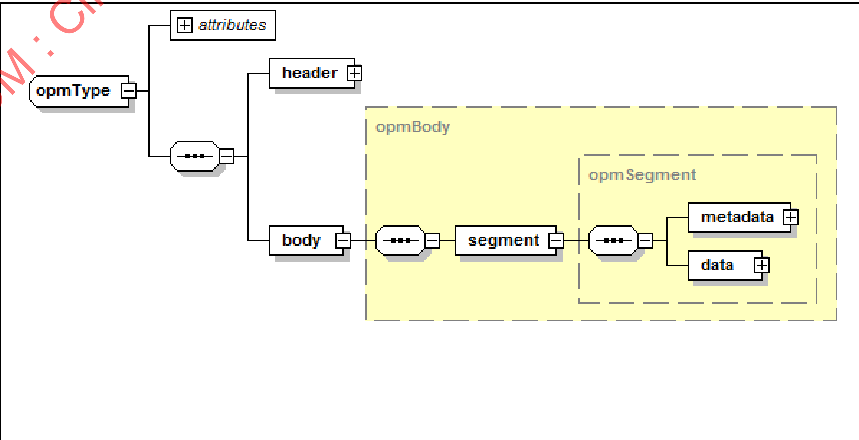

Figure 3-1: NDM/XML Substructure 1 (Single Segment)

3.4 SUBSTRUCTURE 2: AEM, OEM, TDM

3.4.1 The body of NDMs used for messages that describe multiple states or tracking data types (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.

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

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

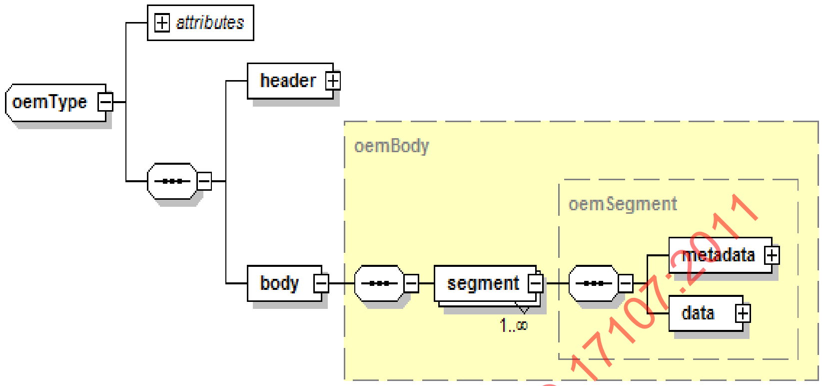

Figure 3-2: NDM/XML Substructure 2 (Possible Multiplicity of Segments)

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, with exceptions as noted in section 4.

NOTES

1 There are three exceptions where 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; and

c) keywords associated with user defined parameters in the ODM Version 2.

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 [1], [2], and [3] 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 reference documents 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 begin and end tags) 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 2^n 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.

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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 [1], [2], and [3].

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 table 4-1.

Table 4-1: NDM/XML Root Element Tags

Root Element Tag	Message Type
<aem></aem>	Attitude Ephemeris Message
<apm></apm>	Attitude Parameter Message
<oem></oem>	Orbit Ephemeris Message
<omm></omm>	Orbit Mean Elements Message
<opm></opm>	Orbit Parameter Message
<tdm></tdm>	Tracking Data Message
<ndm></ndm>	Navigation Data Message (Combined Instantiation Message)

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"
```

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

```
xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml/ndmxml-1.0-
master.xsd"
```

NOTE – The value associated with the `xsi:noNamespaceSchemaLocation` attribute shown in this document is too long to appear on a single line.

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

4.3.5 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.

4.3.6 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.

4.3.7 The CCSDS_xxx_VERS keyword shall be supplied via the ‘id’ attribute of the root element tag (xxx = AEM, APM, etc.).

4.3.8 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:

```
<?xml version="1.0" encoding="UTF-8"?>
<opm  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml/ndmxml-
          1.0-master.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 [1], [2], and [3]. An example `<header>` section is shown immediately below.

```
<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>
```

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 the reference documents (reference [1], [2], and [3]), with exceptions as noted in the 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 reference documents (references [1], [2], and [3]), with exceptions as noted in the 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 [1] shall be '`version="1.0"`'.

4.8.1.5 The standard NDM header shall follow the `<aem>` tag (see 4.4).

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 [1].

NOTE – The rules for including any of the keyword tags in the NDM are the same as those specified for the AEM in reference [1].

4.8.1.9 Tags for keywords specified in reference [1] shall be all uppercase as in reference [1].

4.8.2 SPECIAL TAGS IN THE AEM BODY

NOTE – In addition to the AEM keywords specified in reference [1], 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 the following table:

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 [1].

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 the following table:

<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 <rotation*i*> 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 <rotation*i*> tag.

4.8.2.11 The 'units' attribute may be coded on the <rotation*i*> 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 <rotation*i*> 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 <rotation*i*> tag.

4.8.2.15 The 'units' attribute may be coded on the <rotation*i* > 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 [1] shall be '`version="1.0"`'.

4.9.5 The standard NDM header shall follow the <apm> tag (see 4.4).

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 [1].

NOTE – The rules for including any of the keyword tags in the NDM are the same as those specified for the APM in reference [1].

4.9.9 Tags for keywords specified in reference [1] shall be all uppercase as in reference [1].

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 [1].

4.9.12 The following table illustrates the keyword tags for which units may be specified:

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 [1], 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 [1] 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 the following table:

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 [1].

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 the following table:

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 <rotation*i*> 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 <rotation*i*> tag.

4.9.13.8 The 'units' attribute may be coded on the <rotation*i*> 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 <rotation*i*> 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 `<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>
```

4.10 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 [2] shall be '`version="2.0"`'.

4.10.1.5 The standard NDM header shall follow the <oem> tag (see 4.4).

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

4.10.1.7 Each 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 [2].

NOTE – The rules for including any of the keyword tags in the NDM are the same as those specified for the OEM in reference [2].

4.10.1.9 Tags for keywords specified in reference [2] shall be all uppercase as in reference [2].

4.10.2 SPECIAL TAGS IN THE OEM BODY

NOTE – In addition to the OEM keywords specified in reference [2], 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 The NDM/XML tags used within the <stateVector> structure shall be drawn from the following table:

OEM Tag	Represents	Example
<EPOCH>	time tag of the state	<EPOCH>2007-09-20T17:41:00</EPOCH>
<X>	x component of position	<X units="km">6678.0</X>
<Y>	y component of position	<Y units="km">0.0</Y>
<Z>	z component of position	<Z units="km">0.0</Z>
<X_DOT>	x component of velocity	<X_DOT units="km/s">0</X_DOT>
<Y_DOT>	y component of velocity	<Y_DOT units="km/s">7.73</Y_DOT>
<Z_DOT>	z component of velocity	<Z_DOT units="km/s">0.0</Z_DOT>
<X_DDOT>	x component of acceleration	<X_DDOT units="km/s**2">0.0</X_DDOT>
<Y_DDOT>	y component of acceleration	<Y_DDOT units="km/s**2">0.50</Y_DDOT>
<Z_DDOT>	z component of acceleration	<Z_DDOT units="km/s**2">0.0</Z_DDOT>

4.10.2.3 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 [2].

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

4.10.2.5 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 [2]. Similarly, units are not used in the KVN version of the OEM; however, they are optional in the OPM.

4.10.2.6 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.

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

4.10.2.8 The NDM/XML tags used within the `<covarianceMatrix>` structure shall be drawn from the following table:

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>`

4.10.2.9 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 [2].

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

4.10.2.11 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 [2]. Similarly, units are not used in the KVN version of the OEM covariance matrix; however, they are optional in the OPM and OMM.

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.

4.10.3 CREATING AN OEM VERSION 1 COMPATIBLE INSTANTIATION

NOTES

1 If so desired, the user can create an OEM instantiation that is compatible with the ODM Version 1 (reference [2], annex F) by following the requirements in this section.

2 Figure B-5 in annex B shows an example OEM instantiation that complies with OEM Version 1.0.

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

```
xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml/ndmxml-1.0-master-odmsilver.xsd"
```

NOTE – The value associated with the `xsi:noNamespaceSchemaLocation` attribute shown in this document is too long to appear on a single line.

4.10.3.2 If the user wishes to use XSLT (Extensible Stylesheet Language Transformations) to create a version 1.0 compliant KVN-formatted OEM, then the 'version' attribute of the `<oem>` tag shall be '`version="1.0"`'; otherwise, the user should use '`version="2.0"`'.

4.10.3.3 The user must ***not*** code the `<REF_FRAME_EPOCH>` keyword.

4.10.3.4 The user must ***not*** code the acceleration components of the `<stateVector>` construct.

4.10.3.5 The user must ***not*** code the `<covarianceMatrix>` construct.

NOTE – The placement of comments in XML instantiations of the Version 1 OEM is more restricted than is allowed in KVN instantiations of the Version 1 OEM.

4.10.3.6 In order to create a valid Version 1 OEM XML instantiation, the user should only place comments:

a) at the beginning of the OEM `<header>`;

b) at the beginning of a `<metadata>` section;

c) at the beginning of a `<data>` section.

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-6 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 [2] shall be '<version="2.0"'.

4.11.5 The standard NDM header shall follow the <omm> tag (see 4.4).

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

4.11.7 The 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 [2].

NOTE – The rules for including any of the keyword tags in the NDM are the same as those specified for the OMM in reference [2].

4.11.9 Tags for keywords specified in reference [2] shall be all uppercase as in reference [2].

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 [2].

4.11.12 The following table lists the keyword tags for which units may be specified.

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>

Keyword	Units	Example
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 [2], 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 [2] 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 the following table:

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 [2].

NOTE – The use of <userDefinedParameters> is defined in 4.16.

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-7 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 [2] shall be '`version="2.0"`'.

4.12.5 The standard NDM header shall follow the <opm> tag (see 4.4).

4.12.6 The OPM <body> shall consist of a single (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 [2].

NOTE – The rules for including any of the keyword tags in the NDM are the same as those specified for the OPM in reference [2].

4.12.9 Tags for keywords specified in reference [2] shall be all uppercase as in reference [2].

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 [2].

4.12.12 The following table lists the keyword tags for which units may be specified.

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>

Keyword	Units	Example
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-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 [2], 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 [2] 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 the following table:

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 [2].

NOTE – The use of <userDefinedParameters> is defined in 4.16.

4.12.14 CREATING AN OPM VERSION 1 COMPATIBLE INSTANTIATION

NOTES

1 If so desired, the user can create an OPM instantiation that is compatible with the ODM Version 1 (reference [2], annex F) by following the requirements in this section.

2 Figure B-8 in annex B shows an example OPM instantiation that complies with OPM Version 1.0.

4.12.14.1 The xsi:noNamespaceSchemaLocation must be coded exactly as shown below:

```
xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml/ndmxml-1.0-master-odmsilver.xsd"
```

4.12.14.2 If the user wishes to use XSLT to create a version 1.0 compliant KVN-formatted OPM, then the 'version' attribute of the `<opm>` tag shall be '`version="1.0"`'; otherwise, the user should use '`version="2.0"`'.

4.12.14.3 The user must ***not*** code the `<REF_FRAME_EPOCH>` keyword.

4.12.14.4 The user must code the `<spacecraftParameters>` logical block.

4.12.14.5 The user must ***not*** code the acceleration components of the `<stateVector>` construct.

4.12.14.6 The user must ***not*** code the `<covarianceMatrix>` construct.

4.12.14.7 The user must ***not*** code any `<userDefinedParameters>`.

NOTE – The placement of comments in XML instantiations of the Version 1 OPM is more restricted than is allowed in KVN instantiations of the Version 1 OPM.

4.12.14.8 In order to create a valid Version 1 OPM XML instantiation, the user should only place comments:

a) at the beginning of the OPM `<header>`;

b) at the beginning of the `<metadata>` section;

c) at the beginning of one of the logical blocks.

4.13 CREATING A TDM INSTANTIATION

4.13.1 GENERAL

4.13.1.1 A TDM instantiation shall be delimited with the `<tdm></tdm>` root element tags using the standard attributes documented in 4.3.

NOTE – Figure B-9 in annex B provides an example TDM instantiation.

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

4.13.1.3 The 'id' attribute shall be '`id="CCSDS_TDM_VERS"`'.

4.13.1.4 The 'version' attribute for the version of the TDM described in reference [3] shall be '`version="1.0"`'.

4.13.1.5 The standard NDM header shall follow the `<tdm>` tag (see 4.4).

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

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

4.13.1.8 The keywords in the `<metadata>` and `<data>` sections shall be those specified in reference [3].

NOTE – The rules for including any of the keyword tags in the NDM are the same as those specified for the TDM in reference [3].

4.13.1.9 Tags for keywords specified in reference [3] shall be all uppercase as in reference [3].

4.13.2 SPECIAL TAGS IN THE TDM BODY

NOTE – In addition to the TDM keywords specified in reference [3], there is a special tag associated with the TDM body as described in the next subsection.

4.13.2.1 The `<observation>` tag shall be used to encapsulate the keywords associated with one of the tracking data types in the TDM.

4.13.2.2 The `<observation>` tag shall consist of two subcomponents:

a) the time tag (`<EPOCH>` tag); and

b) one specific data type (e.g., `<RECEIVE_FREQ>`).

NOTE – Thus a received frequency observation would appear in an NDM/XML TDM as follows:

```
<observation>
   <EPOCH>2008-200T12:34:56.789</EPOCH>
   <RECEIVE_FREQ>8415000000</RECEIVE_FREQ>
</observation>
```

4.14 CREATING AN NDM COMBINED INSTANTIATION

NOTE – It is possible to create an XML instance that incorporates any number of AEM, APM, OEM, OMM, OPM, and/or TDM messages in a logical suite called an 'NDM combined instantiation'. Note that the OEM Version 1 and OPM Version 1 are not supported in an NDM combined instantiation.

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

4.14.2 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.

4.14.3 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 AEM, APM, OEM, OMM, OPM, and TDM subsections 4.8 through 4.13.

4.14.4 Between the <ndm></ndm> tags, the desired message tags described in 4.8 through 4.13 may be combined.

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

4.14.6 In general, an NDM combined instantiation should consist of at least one message (AEM, APM, OEM, OMM, OPM, or TDM).

4.14.7 An 'empty' NDM, i.e., an NDM that contains only the outermost tag levels may be useful for some purposes.

4.15 DISCUSSION

In the example shown in figure 4-1, all of the detail has been removed to illustrate the structure of an NDM combined instantiation. A special usage of combined messages could be for a constellation of spacecraft. Another potential use is where an attitude data message depends upon a particular orbital state. For example, an APM and its associated OPM could be conveniently conveyed in a single NDM. Figure 4-1 contrasts the single message NDM with an NDM combined instantiation. The basic structure of an NDM combined instantiation is illustrated in figure 4-2. 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 tag.

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

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

```
<ndm>
<COMMENT> generally, at least
one AEM, APM, OEM, OMM, OPM, or
TDM.</COMMENT>
<COMMENT> Note:  the
constituent messages can occur
in any quantity (including 0)
or order.</COMMENT>

      <aem>
      </aem>
      <apm>
      </apm>
      <oem>
      </oem>
      <omm>
      </omm>
      <opm>
      </opm>
      <tdm>
      </tdm>
</ndm>
```

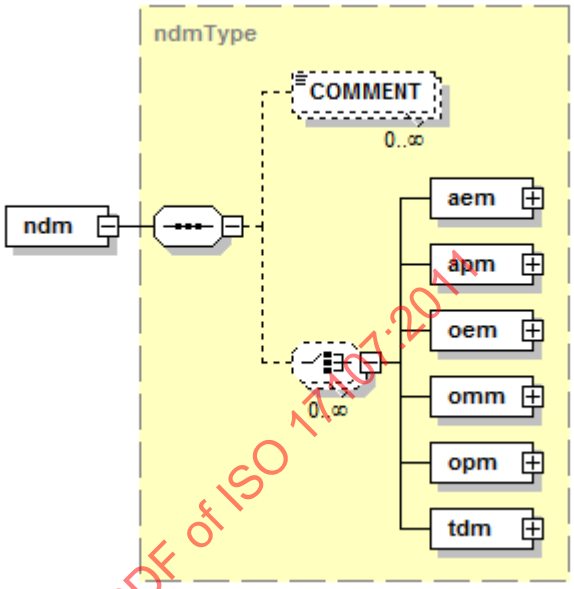

Figure 4-2: NDM Combined Instantiation Basic Structure

```
<?xml version="1.0" encoding="UTF-8"?>
<ndm  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"

xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml/ndmxml-1.0-
master.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>


   <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>


   <tdm id="CCSDS_TDM_VERS" version="1.0">
      <header>
      </header>
      <body>
      </body>
   </tdm>

</ndm>
```


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

4.16 USER DEFINED PARAMETERS

NOTE – The ODM Version 2.0 (reference [2]) 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>`.

4.16.1 GENERAL

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

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

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

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

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

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

4.16.1.7 All information about the user-defined parameters shall be conveyed via two attributes of the `<USER_DEFINED>` tag, specifically, the attributes 'parameter' and 'value'.

4.16.1.8 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.

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

4.16.2 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>
```

ANNEX A

INFORMATION SECURITY

(INFORMATIVE)

A1 OVERVIEW

A1.1 ANALYSIS OF SECURITY CONSIDERATIONS

This section 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 preparing pointing and frequency predicts used during spacecraft commanding, and the messages can be used 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, and (b) unauthorized access to the messages during transmission between exchange 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.

A2 SECURITY CONCERNS RELATED TO THIS RECOMMENDED STANDARD

A2.1 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.

A2.2 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.

A2.3 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.

A2.4 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.

A2.5 CONTROL OF ACCESS TO RESOURCES

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

A2.6 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.

A3 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.

A4 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.

ANNEX B

EXAMPLE NDM/XML SCHEMA INSTANTIATIONS

(INFORMATIVE)

B1 GENERAL

The schema set associated with this standard is available via the CCSDS SANA repository:

http://sanaregistry.org/r/ndmxml/

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

http://cwe.ccsds.org/moims/docs/MOIMS-NAV/NDM-XML-TestFiles/

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/ndmxml-1.0-master.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>
      &lt;segment&gt;
         <metadata>
            <COMMENT>This file was produced by M.R. Somebody, MSOO 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>
```


Figure B-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 B-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="http://sanaregistry.org/r/ndmxml/ndmxml-1.0-master.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 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/ndmxml-1.0-master.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>
      &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 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>
```


Figure B-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_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>
      &lt;/segment&gt;
   </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/ndmxml-1.0-master.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>
      &lt;segment&gt;
         <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>
```


Figure B-4: Sample NDM/XML OEM

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


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