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

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National foreword

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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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Foreword

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Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

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.

Page 1-3

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.



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

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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.

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XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

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:

- o 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.
- o 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.
- o 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.

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

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.

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

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- Agenzia Spaziale Italiana (ASI)/Italy.
- Canadian Space Agency (CSA)/Canada.
- Centre National d'Etudes Spatiales (CNES)/France.
- China National Space Administration (CNSA)/People's Republic of China.
- Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)/Germany.
- European Space Agency (ESA)/Europe.
- Instituto Nacional de Pesquisas Espaciais (INPE)/Brazil.
- Japan Aerospace Exploration Agency (JAXA)/Japan.
- National Aeronautics and Space Administration (NASA)/USA.
- Federal Space Agency (FSA)/Russian Federation.
- UK Space Agency/United Kingdom.

Observer Agencies

- Austrian Space Agency (ASA)/Austria.
- Belgian Federal Science Policy Office (BFSP0)/Belgium.
- Central Research Institute of Machine Building (TsNIIMash)/Russian Federation.
- China Satellite Launch and Tracking Control General, Beijing Institute of Tracking and Telecommunications Technology (CLTC/BITTT)/China.
- Chinese Academy of Sciences (CAS)/China.
- Chinese Academy of Space Technology (CAST)/China.
- Commonwealth Scientific and Industrial Research Organization (CSIRO)/Australia.
- CSIR Satellite Applications Centre (CSIR)/Republic of South Africa.
- Danish National Space Center (DNSC)/Denmark.
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- European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)/Europe.
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- Geo-Informatics and Space Technology Development Agency (GISTDA)/Thailand.
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- Indian Space Research Organization (ISRO)/India.
- Institute of Space Research (IKI)/Russian Federation.
- KFKI Research Institute for Particle & Nuclear Physics (KFKI)/Hungary.
- Korea Aerospace Research Institute (KARI)/Korea.
- Ministry of Communications (MOC)/Israel.
- National Institute of Information and Communications Technology (NICT)/Japan.
- National Oceanic and Atmospheric Administration (NOAA)/USA.
- National Space Agency of the Republic of Kazakhstan (NSARK)/Kazakhstan.
- National Space Organization (NSPO)/Chinese Taipei.
- 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.

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

- United States Geological Survey (USGS)/USA.

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

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

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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.

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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].

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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,

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- 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.

XML SPECIFICATION FOR NAVIGATION DATA MESSAGES

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

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(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.

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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).