The Consultative Committee for Space Data Systems

Proposed Recommendation for
Space Data System Standards

NAVIGATION HARDWARE MESSAGE

PROPOSED RECOMMENDED STANDARD

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FOREWORD

This document is a Proposed Standard for Navigation Hardware Messages and has been prepared by the Consultative Committee for Space Data Systems (CCSDS). The Navigation Hardware Message described in this Proposed Standard is the baseline concept for spacecraft hardware data interchange applications that are cross-supported between Agencies of the CCSDS.

This Proposed Standard establishes a common framework and provides a common basis for the format of spacecraft hardware data exchange between space agencies. 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 Proposed Standard and may incorporate features not addressed by this Proposed Standard.

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PREFACE

This document is a Proposed CCSDS Standard. Its ‘White Book’ status indicates that the CCSDS believes the document to be technically immature and has not released it for formal review by appropriate technical organizations. As such, its technical contents are not stable, and several iterations of it may occur in response to comments received during the review process.

Implementers are cautioned not to fabricate any final equipment in accordance with this document’s technical content.

DOCUMENT CONTROL

Document	Title and Issue	Date	Status
CCSDS 510.0-W-1	Navigation Hardware Message, Draft Recommended Standard, Issue 0	November 2010	First Draft
CCSDS 510.0-W-2	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	November 2011	More Complete Draft
CCSDS 510.0-W-3	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	January 2012	Draft Containing Suggested Changes
CCSDS 510.0-W-4	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	May 2012	Changes to Formats
CCSDS 510.0-W-5	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	July 2012	Modifications of tables in annexes and correction of errors
CCSDS 510.0-W-6	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	November 2012	Addition of XML representation and changes resulting from discussions at Working Group meeting, Oct. 2012
CCSDS 510.0-W-7	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	February 2013	Modification to source of mnemonic definitions and reformatting of entire document
CCSDS 510.0-W-8	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	January 2014	Incorporation of suggestions from Spring and Fall 2013 technical meeting and following reviews
CCSDS 510.0-W-9	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	June 2014	Addition of Frame and Calcurve Keywords and incorporation of suggestions from Spring 2014 meeting

CCSDS 510.0-W-11	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	December 2014	Addition of changes suggested at working group meeting including removal of Frame and Calcurve Keywords
CCSDS 510.0-W-12	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	May 2015	Addition of changes from reviewers including a complete rewrite of Sections 3 and 5
CCSDS 510.0-W-13	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	October 2015	Addition of changes from reviewers to Version 12
CCSDS 510.0-W-14	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	November 2015	Interchanged Sections 4 and 5.
CCSDS 510.0-W-15	Navigation Hardware Message, Proposed Recommended Standard, Issue 1	November 2015	Addition of changes from reviewers to Version 14.

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1 INTRODUCTION

1.1 PURPOSE

The Navigation Hardware Message (NHM) is intended to provide a uniform format for the transmission of data from a ground system functional group that receives and unpacks spacecraft telemetry to any spacecraft functional group that uses spacecraft navigation data for determination or analysis of the spacecraft attitude or orbit. Onboard hardware data that can be used for spacecraft navigation is called Navigation Hardware Data.

This document includes goals and criteria that the message format has been designed to meet. For exchanges where these requirements do not capture the needs of the participating agencies another mechanism could be selected.

1.2 SCOPE

This Proposed Standard contains the specifications for a Navigation Hardware Message designed for spacecraft navigation applications that input hardware data. These applications include monitoring of the performance of the spacecraft onboard attitude determination and control, its onboard orbit determination (if applicable), and its navigation hardware, as well as calibration of spacecraft navigation hardware. The term “Hardware Data” is used in this document to include both data produced by navigation hardware and data that results from onboard processing of the data produced by the hardware. Similarly, the term “measurement” is used in this document to include both hardware measurements and processed hardware measurements or any other information that is generated concerning the state of the spacecraft navigation hardware. Although the NHM is designed for transmission of navigation hardware data, the standard could also be applied to spacecraft data intended for other purposes such as monitoring of functions that are not navigation related.

The Proposed Standard cannot explicitly include all types of Navigation Hardware data that exist or will exist in the future. It is intended to contain a syntax which can be used to define the transmission of those spacecraft hardware data that are not explicitly included.

Definition of the accuracy of data in any particular NHM is outside the scope of this Proposed Standard. An Interface Control Document (ICD) between data exchange participants is the preferred means for defining accuracies. This ICD can also be used to define any non-standard hardware data formats that might be required.

Because of the enormous number of hardware types each of which has its own outputs and its own internal measurement units, and because hardware types are frequently modified and developed, it is anticipated that ICDs will generally be the most common and most desirable means of documentation of the idiosyncrasies of the hardware.

1.3 APPLICABILITY

Telemetry Data is transmitted from spacecraft to ground stations according to established standards. This document does not address those standards. This Proposed Standard is applicable only to the message format and content, but not to its transmission. The method of transmitting the message between exchange partners is beyond the scope of this document and will generally be specified in the ICD. Message transmission could be based on a CCSDS data transfer protocol, file based transfer protocol such as SFTP, stream-oriented media, or other secure transmission mechanism. In general, the transmission mechanism will not place constraints on the technical data content of an NHM.

1.4 RATIONALE

Spacecraft hardware data are used for many required ground-processing functions. Navigation Hardware data is essential to perform the underlying functions of navigation, but there is presently no uniform standard for their formatting.

In order for a standard to be useful it is necessary that it applies to the many thousands of types of hardware measurement data that exist and be flexible enough to be adaptable to new spacecraft hardware.

The approach taken in this proposed standard is to avoid explicitly enumerating all of the possible hardware measurement data, but instead to provide a flexible syntax through which present and future hardware data could be identified.

1.5 DOCUMENT STRUCTURE

This document consists of several sections plus annexes.

- Section 1 contains an overview of the standard, a description of the structure of this document and of the conventions and common material used in it.
- Section 2 provides a brief overview of the CCSDS-recommended Navigation Hardware Message (NHM).
- Section 3 provides details about the structure and content of the NHM in the KVN format.
- Section 4 provides details about the syntax used in the NHM in the KVN format.
- Section 5 provides details about the structure and content of the NHM in the XML format.
- Section 6 provides details about the syntax used in the NHM in the XML format.
- Annex A contains an Implementation Conformance Statement (ICS) pro forma that may be used by implementers to compactly describe their implementations.
- Annex B provides a normative list of approved Values for the NHM TIME_SYSTEM Keyword.
- Annex C discusses Security, SANA and patent considerations.

– Annex D provides tables of examples of Values for fields composing the Mnemonic Keyword along with a description of the information that would be provided in an ICD for each field.

– Annex E provides examples of NHM Mnemonic Keywords with corresponding ICD Information.

– Annex F shows how data from various types of spacecraft hardware can be accommodated using the NHM in KVN format, via several examples.

– Annex G contains an example of an NHM in XML format.

– Annex H contains a list of informative references.

– Annex I contains a description of the requirements and criteria that the message format has been designed to meet.

– Annex J contains a graphical representation of the NHM structure in KVN format.

1.6 DEFINITIONS AND CONVENTIONS

Conventions and definitions of navigation concepts such as reference frames, time systems, etc., are provided in references [H2], [H3].

1.6.1 Terms

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

Navigation Hardware: consists of the sensors and actuators that are the source of data involved in any computations of spacecraft orbit or attitude.

Navigation Hardware Data: includes all Values originating from Navigation Hardware including both unprocessed measurements and processed results.

Keyword = Value Notation (KVN): denotes a format which associates a Value with a Keyword. The Keyword designates an important property or attribute of the subject under discussion, and the Value consists of one or more data items which represent measurements or descriptive states of that property.

Mnemonic Keyword: denotes an alphanumeric string that is associated with a particular grouping of Navigation Hardware Data. Each Mnemonic Keyword string is defined in the Metadata section of the message (see Section 3.3) and is used in the Data section of the message.

eXtensible Markup Language (XML): denotes a language in which the NHM can optionally be expressed (see reference [1], [2]).

Interface Control Document (ICD): denotes a formal agreement between the data transmission and data receipt entities. It is not limited to documents with the title “Interface Control Document.”

Space Assigned Numbers Authority (SANA): is the registrar function for the protocol registries created under the CCSDS.

1.6.2 NOMENCLATURE

The following conventions apply for the normative specifications in this document:

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.

NOTE – These conventions do not imply constraints on diction in text that is clearly informative in nature.

1.6.3 Conventions

The term ‘n/a’ or ‘N/A’ denotes an attribute that is not applicable or not available.

In this document, the term ‘ASCII’ is used generically to refer to the text character set defined in reference [4].

CamelCase. A style of capitalization in which the initial characters of concatenated words are capitalized, as in *CamelCase*.

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

1.7 REFERENCES

The following documents contain, through reference in this text, provisions of this Proposed Standard. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Proposed 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 documents.

[1] *XML Schema Part 1: Schema*. 2nd ed. P. Biron and A. Malhotra, eds. W3C Recommendation 28. n.p.: W3C, 2004.

[2] *XML Schema Part 2: Datatypes*. 2nd ed. P. Biron and A. Malhotra, eds. W3C Recommendation 28. n.p.: W3C, 2004.

[3] *The International System of Units (SI),* 8th edition, Bureau International des Poids et Mesures, Organisation Intergouvernementale de la Convention du Mètre, STEDI MEDIA, Paris, 2006.

[4] *Information Technology—8-Bit Single-Byte Coded Graphic Character Sets—Part 1: Latin Alphabet No. 1*. International Standard, ISO/IEC 8859-1:1998. Geneva: ISO, 1998.

[5] *Time Code Formats*. Recommendation for Space Data System Standards, CCSDS 301.0-B-4. Blue Book. Issue 4. Washington, D.C.: CCSDS, November 2010.

[6] IEEE Standard for Binary Floating-Point Arithmetic. IEEE Std 754-1985. New York: IEEE, 1985.

[7] *XML Specification for Navigation Data Messages*. Recommendation for Space Data System Standards, CCSDS 505.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, December 2010.

[8] *United Nations Online Registry of Objects Launched into Outer Space* http://www.unoosa.org/oosa/osoindex/index.jspx

2 NAVIGATION HARDWARE MESSAGE OVERVIEW

2.1 GENERAL

This section provides a high-level overview of the CCSDS recommended Navigation Hardware Message (NHM).

This Navigation Hardware Message Proposed Standard specifies a message format for use in exchanging spacecraft hardware data used in navigation processes. The data is exchanged between parties that provide such data and parties that use it. For example, data may be transmitted from an agency that receives spacecraft telemetry containing hardware data to other agencies that use spacecraft hardware data. The hardware data must first be unpacked from the telemetry before distribution in the NHM format.

Typically, the data will arise from onboard measurements (such as sensor measurements) or onboard calculations that are involved in attitude or orbit determination. The data is used in ground facilities to monitor and analyze performance of the hardware and of the onboard use of the hardware data. The standardization of hardware data formats facilitates development of software to perform the desired monitoring and analysis functions and reduces the risk of error in such software.

The NHM is intended to facilitate the use of navigation hardware data in ground monitoring, validation, and analysis of spacecraft navigation performance. Its use is expected to reduce from mission to mission the amount of software modification necessary to transmit and receive navigation hardware data. It is also expected to allow visual examination of the text of the message to provide easy understanding of the nature of any data in the message.

For a single mission, multiple NHMs may be desired for different users. For example:

- An Attitude NHM containing the output of attitude sensors and the results of their onboard processing (such as onboard attitude estimates, rate biases, etc.) sent to the attitude validation team.
- An Orbit NHM containing output of orbit determination hardware (e.g. GPS receivers, accelerometers, thrusters, etc.) and the results of any onboard orbit processing sent to the orbit determination team.
- A Health and Safety Monitoring NHM containing output of any onboard hardware or results of hardware processing that are needed for monitoring the spacecraft navigation systems health and safety (e.g. temperatures, pressures, battery charge, hardware status) sent to the mission operations team.

It is expected that the data in various messages might not be exclusive. For example, both the Attitude NHM and the Health and Safety Monitoring NHM could contain data on the status of attitude hardware.

For each NHM it is expected that:

- Identical (or at least similar) forms will be used for corresponding data from different missions.
- Mnemonic Keywords will be constructed to be as clear as possible.
- ICDs will be used to describe the contents of each type of Hardware Data Record.

2.2 THE NAVIGATION HARDWARE MESSAGE (NHM) BASIC FORMAT

2.2.1 The NHM in this version of the Proposed Standard is ASCII-text formatted. While binary-based NHM formats are computer efficient and minimize overhead during data transfer, there are ground-segment applications for which an ASCII character-based message is more appropriate. For example, ASCII format character-based hardware data representations are useful in transferring data between heterogeneous computing systems, because the ASCII character set is nearly universally used and is interpretable by all popular systems. In addition, direct human-readable dumps of text to displays, emails, documents or printers are possible without preprocessing. The penalty for this convenience is some measure of inefficiency (based on early tests, such penalty would be greatly reduced if the data is compressed for transmission).

2.2.2 The NHM is realized as a sequence of plain ASCII text lines (reference [4]), which can be in either a file format or a real-time stream. The content is separated into three basic parts as described in section 3. These parts are the Header, Metadata, and Data. The NHM architecture provides flexibility by defining a syntax which can be used to specify hardware data contents, and provides consistency by defining Values that correspond to commonly used hardware.

2.2.3 The ASCII text in an NHM can be exchanged in either of two formats: a KVN or an XML format (see 1.6.1). The KVN formatted NHM is described in sections 3 and 4 of this document. Description of the message format based on XML is detailed in sections 5 and 6 of this document. It is suggested that an ICD specify which NHM ASCII format will be exchanged, the KVN or the XML format, as agreed by the exchange participants.

3 NAVIGATION HARDWARE MESSAGE CONTENT AND STRUCTURE IN KVN

3.1 GENERAL

The NHM may be represented in KVN format (Keyword = Value Notation). This section applies to KVN format only. The Syntax of the NHM lines in KVN format is specified in Section 4. A graphical representation of the KVN NHM structure is presented in Annex J.

3.1.1 The NHM shall consist of digital data represented as ASCII text lines (see reference [4]) .

3.1.2 An NHM shall contain Hardware Data for a single spacecraft.

3.1.3 An NHM shall contain one each of:

a) a Header Section (see section 3.2);

b) a Metadata Section (see section 3.3); and

c) a Data Section (see section 3.4).

3.1.4 The Header, Metadata, and Data Sections shall appear in the order presented in 3.1.3.

3.1.5 An NHM shall be exchangeable as either a real-time stream or as a file.

3.1.6 NHM exchange methods should be decided on a case-by-case basis by the participating parties and documented in an ICD. The exchange method shall not constrain the data content.

3.1.7 The NHM file naming scheme should be agreed to on a case-by-case basis between the participating parties, typically specified in an ICD.

3.2 NHM HEADER SECTION

3.2.1 The NHM shall include a Header that consists of information that identifies the basic parameters of the message. Note: the syntax of lines in the Header Section is described in Section 4.2.

3.2.2 The allowed elements in the Header Section are the following, which must be in the order presented:

a) A mandatory line specifying the format version of the message;

b) An optional set of Comment lines;

c) A mandatory line specifying the creation date of the message; and

d) A mandatory line specifying the originator of the message.

3.3 NHM METADATA SECTION

3.3.1 The NHM shall include a Metadata Section that consists of information that describes the data content of the message. Note: the syntax of lines in the Metadata Section is described in Section 4.3.

3.3.2 The allowed elements in the Metadata Section are the following, which must be in the order presented:

a) A mandatory single line designating the start of the Metadata Section: the Metadata Start Line;

b) One or more optional Comment lines;

c) A mandatory single line specifying the Time System used in the message: the Time System Line;

d) A mandatory single line specifying the Name of the single Spacecraft from which the message data originates: the Object Name Line;

e) A mandatory single line specifying the Identification Designator of the single Spacecraft from which the message data originates: the Object Identifier Line;

f) An optional single line specifying the Start Time of the data: the Start Time Line;

g) An optional single line specifying the Stop Time of the data: the Start Time Line;

h) At least one mandatory Define Block specifying the form of the data in the Data Section associated with the Keyword defined in the Define Block;

i) A mandatory single line designating the end of the Metadata Section: The Metadata End Line.

3.3.3 A Define Block shall start with a Define Line, defining a Mnemonic Keyword that will be used in the data section of the message.

> Note – The Define Line and the Mnemonic Keyword defined in it are the key, essential features of the NHM.
> The purpose of the Define Line is to provide information on the source, number, and type data in each line in the Data Section. The data in each line are logically related (pertain to the same hardware and intended to be used together) and have a common time tag and sampling frequency.
> The String defined as the Value of the Define Line will serve as the Keyword on lines in the Data Section.

3.3.4 A Define Block may contain multiple comments following the Define Line.

3.4 NHM DATA SECTION

3.4.1 The NHM shall include a Data Section that contains the navigation hardware data. Note: the syntax of lines in the Data Section is described in Section 4.4.

3.4.2 The allowed elements in the Data Section are the following, which must be in the order presented:

a) A mandatory single line designating the Start of the Data Section: the Data Start Line

b) One or more optional Comment lines;

c) At least one mandatory lines containing the Data: Hardware Data Records;

d) A mandatory single line designating the End of the Data Section immediately after the last Hardware Data Record (3.4.2 b): the Data Stop Line.

4 NAVIGATION HARDWARE MESSAGE KVN SYNTAX

4.1 GENERAL

This section describes the syntax of each type of line in an NHM in the KVN format.

4.1.1 Each line in the NHM, with the exceptions specified below, shall have the following generic format:

Keyword = Value

4.1.2 Comment lines in all sections of the NHM shall consist of the string "COMMENT" followed by any string of ASCII characters. There shall be no equals sign ("=") between the string "COMMENT" and the string of ASCII characters.

Note: This is an exception to KVN Notation.

4.1.3 In Fields that represent a time tag, times shall be given in one of the following two formats:
yyyy-mm-ddThh:mm:ss[.d→d][Z]
or
yyyy-dddThh:mm:ss[.d→d][Z]
where 'yyyy' is the year, 'mm' is the two-digit month, 'dd' is the two-digit day-of-month and 'ddd' is the three-digit day of the year, separated by hyphens, 'T' is a fixed separator between the date and time portions of the string, and 'hh:mm:ss[.d→d]' is the time in hours, minutes, seconds and fractional seconds, separated by colons. As many 'd' characters to the right of the period as required may be used to obtain the required precision, up to the maximum allowed for a fixed-point number. The final character "Z" may be appended if the time is in UTC. (see Reference 5.)

4.1.4 Fields that represent Data shall contain Integer Values, Fixed-Point Values, Floating-Point Values, Text Values, or Binary Values.

4.1.4.1 Integer values shall consist of a sequence of decimal digits with an optional leading sign (‘+’ or ‘-’). If the sign is omitted, ‘+’ shall be assumed. Leading zeros may be used. The range of values that may be expressed as an integer is:
-2 147 483 648 <= x <= +2 147 483 647 (i.e., -231 <= x <= 231-1).

4.1.4.2 Fixed-point Value notation shall consist of a sequence of decimal digits separated by a period as a decimal point indicator, with an optional leading sign (‘+’ or ‘-’). If the sign is omitted, ‘+’ shall be assumed. Leading and trailing zeros may be used. At least one digit shall be used before and after a decimal point. The number of digits shall be 16 or fewer.

4.1.4.3 Floating-point Value notation shall consist of a sign, a mantissa, an alphabetic character indicating the division between the mantissa and exponent, and an exponent, constructed according to the following rules:

- The sign may be ‘+’ or ‘-’. If the sign is omitted, ‘+’ shall be assumed.
- The mantissa must be a string of no more than 16 decimal digits with a decimal point ‘.’ in the second position of the ASCII string, separating the integer portion of the mantissa from the fractional part of the mantissa.
- The character used to denote exponentiation shall be ‘E’ or ‘e’. If the character indicating the exponent and the following exponent are omitted, an exponent value of zero shall be assumed (essentially yielding a fixed-point value).
- The exponent must be an integer, and may have either a ‘+’ or ‘-’ sign (if the sign is omitted, then ‘+’ is assumed).
- The maximum positive floating-point value is approximately 1.798E+308, with 16 significant decimal digits precision. The minimum positive floating-point value is approximately 4.94E-324, with 16 significant decimal digits precision.

NOTE – These specifications for integer, fixed-point, and floating-point values conform to the XML specifications for the data types four-byte integer ‘xsd:int’, ‘decimal’, and ‘double’, respectively (see reference [6]). The specifications for floating point values conform to the IEEE 754 double precision type (see reference [7]). Floating-point numbers in IEEE extended-single or IEEE extended-double precision may be represented, but do require an ICD between participating agencies because of their implementation specific attributes. The special values ‘NaN’, ‘-Inf’, ‘+Inf’, and ‘-0’ are not supported in the NHM.

4.1.4.4 Blanks shall not be permitted within numeric values and time values.

4.1.4.5 In Text Value fields an underscore shall be equivalent to a single blank.

4.1.4.6 Binary Value Fields shall consist of a single digit which shall be either 1 or 0.
NOTE – The significance of the Values 1 and 0 for each Binary Value Field should be established in and ICD.

4.2 HEADER SECTION SYNTAX

4.2.1 Format Version

4.2.1.1 The Keyword of the Format Version Line shall be “CCSDS_NHM_VERS”.

4.2.1.2 The Value in the Format Version Line shall be version in the form of ‘x.y’, where ‘y’ shall be incremented for corrections and minor changes, and ‘x’ shall be incremented for major changes. Format versions 0.y are reserved for test versions of the message.

4.2.2 Creation Date

4.2.2.1 The Keyword of the Creation Date Line shall be “CREATION_DATE”.

4.2.2.2 The Value in the Creation Date Line shall be the Message creation date and time in UTC.

4.2.3 Message Originator

4.2.3.1 The Keyword of the Message Originator line shall be “ORIGINATOR”.

4.2.3.2 The Value in the Message Originator Line shall identify the agency or other creator of the message. This Value should be drawn from a SANA registry at: http://sanaregistry.org/r/organizations/organizations.html.

Note: A summary of the NHM Header syntax with examples is provided in Table 4-1.

Table 4-1. Summary of NHM Header Section Syntax

Keyword	Description	Mandatory
CCSDS_NHM_VERS	Format version in the form of ‘x.y’, where ‘y’ shall be incremented for corrections and minor changes, and ‘x’ shall be incremented for major changes. See 4.2.1 and 4.2.2[JH2]	Yes
Examples: CCSDS_NHM_VERS = 0.12 CCSDS_NHM_VERS = 1.0		
COMMENT	See 4.1.2	No
Example: COMMENT This is important		
CREATION_DATE	Data creation date/time in UTC. For format specification, see 4.2.3 and 4.2.4	Yes

Examples: CREATION_DATE = 2001-11-06T11:17:33 CREATION_DATE = 2002-204T15:56:23.4 CREATION_DATE = 2006-001T00:00:00Z		
`ORIGINATOR`	Creating agency. This Value should be drawn from a SANA registry at: http://sanaregistry.org/r/organizations/organizations.html. See 4.2.5 and 4.2.6	Yes
Examples: ORIGINATOR = CNES ORIGINATOR = ESOC ORIGINATOR = GSFC		

4.3 METADATA SECTION SYNTAX

4.3.1 Start Line

4.3.1.1 The Keyword of the first line of the Metadata Section shall be “META_START”.

4.3.1.2 There shall be no Value for the META_START line. This is an exception to the KVN notation.

4.3.2 Time System Line

4.3.2.1 The line specifying the Time System shall have the Keyword “TIME_SYSTEM”.

4.3.2.2 The Value in the line specifying the Time System shall be selected from the full set of allowed Values enumerated in Annex B.

4.3.3 Object Name Line

4.3.3.1 The line specifying the Object Name shall have the Keyword “OBJECT_NAME”.

4.3.3.2 The Value in the line specifying the Object Name may have any Value but it is recommended to use names from the United Nations Online Registry of Objects Launched into Outer Space (Reference [8])) which includes the Object Name and international designator of the participant.

4.3.4 Object Identity[JH3] Line

4.3.4.1 The line specifying the Object Identity shall have the Keyword “OBJECT_ID”.

4.3.4.2 The Value in the line specifying the Object Identity may have any Value but it is recommended that the Values be drawn from the United Nations Online Registry of Objects Launched into Outer Space (Reference [8])). If this source is chosen, it is recommended that Values have the format YYYY-NNNP{PP}, where:
– YYYY = year of launch;
– NNN = three-digit serial number of launch in year YYYY (with leading zeros);
– P{PP} = at least one capital letter for the identification of the part brought into space by the launch.
In cases where the asset is not listed in the registry, the Value should be provided in an ICD.

Start Time Line

4.3.4.3 The line specifying the Message Start Time shall have the Keyword “START_TIME”.

4.3.4.4 The Value in the line specifying the Message Start Time shall be the earliest time of the Hardware Data immediately following the Metadata Section. The Start Time Value shall be relative to the time system specified by the TIME_SYSTEM Keyword.

4.3.5 Stop Time Line

4.3.5.1 If a Message Stop Time Line exists it shall have the Keyword "STOP_TIME".

4.3.5.2 The Value in the Stop Time Line shall be the latest time of the Hardware Data immediately following the Metadata Section. The Stop Time Value shall be relative to the time system specified by the TIME_SYSTEM Keyword.

4.3.6 Define Block

4.3.6.1 There shall be at least one Define Block in the Metadata Section.

4.3.6.2 Each Define Block shall contain a single Define Line followed by an arbitrary number of Comment lines.

Note: Syntax for the Comment Lines is specified in Section 4.1.2.

4.3.6.3 The Keyword of a Define Line shall be "DEFINE".

4.3.6.4 The Value in a Define Line shall be an ASCII string with four mandatory fields (the System Field, the Hardware Type Field, the Data Group Field, and the Measurement Count Field) and one optional field (the Measurement Type Field), separated by period characters ".".

Note: The string composing the Value in a Define Line is called a Mnemonic Keyword. A summary of the Mnemonic Keyword Syntax with examples is provided in Table 4-2. The Mnemonic Keyword is used as the Keyword in lines in the Data Section. The fields in the Mnemonic Keyword describe the data that appears on the corresponding lines in the Data Section.

4.3.6.4.1 The System Field shall represent the Spacecraft System from which the data arises and shall be selected from those in a SANA registry (see Annex D) or specified in an ICD. Every effort should be made to select a Value from the SANA registry.

4.3.6.4.2 The Hardware Type Field shall start with an upper case alphabetic string containing exactly three characters followed by an integer of arbitrary length that specifies the instance of this hardware. If only one instance exists, the Value (1) must be used. The three character code must be either selected from those in a SANA registry (see Annex D) or specified in an ICD. Every effort should be made to select a Value from the SANA registry.

4.3.6.4.3 The Data Group Field shall be an arbitrary string of alphanumeric characters starting with an alphabetic character that identifies the set of data arising from the hardware. The set of Data Group Fields for a mission should be specified in an ICD.

4.3.6.4.4 If more than one instance of a data group is possible, a numerical designator of the instance referred to shall be the last character(s) in the field.

4.3.6.4.5 The Measurement Count Field shall consist of the letter “V” followed by an integer specifying the total number of Data Fields that will occur on each line in the Data Section in which this Mnemonic Keyword appears.

4.3.6.4.6 The Measurement Type field (if it exists) shall be a string consisting of a series of ASCII characters representing the type of the data of each of the Data Fields (in lines in the Data Section with the corresponding Mnemonic Keyword), each optionally followed by an integer.

- There must be one character in the Measurement Type Field for each of the Data Fields in the Hardware Data Record containing the Mnemonic Keyword except that if the same Measurement Types are repeated, a single character followed by an integer representing the number of repetitions may be used.
- The symbols indicating the Measurement Types shall be in the same order that the Data Fields associated with this Mnemonic Keyword will appear on records in the Data Section.
- The Measurement Types shall be selected from those in Table 4-2.

Table 4-2. Summary of NHM Mnemonic Keywords Syntax

Field	Description	Examples	Mandatory
SYSTEM	A code representing the spacecraft system from which the data comes. The Values of this field shall be selected from those in a SANA registry (see Annex D) or specified in an ICD. Every effort should be made to select a Value from the SANA registry.	ACS PRP THM	Yes
HARDWARE TYPE	The Hardware Type field shall start with an upper case alphabetic string containing exactly three characters followed by an integer that specifies the instance of this hardware. If only one instance exists, the Value (1) must be used. The three character code must be either selected from those in a SANA registry (see Annex D) or specified in an ICD. Every effort should be made to select a Value from the SANA registry.	STA3 OBC1 GPS2	Yes
DATA GROUP	An arbitrary string of alphanumeric characters that identifies the set of data arising from the hardware. This string and necessary descriptive info should be specified in an ICD. The first character in this field shall be alphabetical. If more than one instance of a data group is possible, a numerical designator of the instance referred to shall be the last character(s) in the field.	STAR1 A PSR	Yes
MEASUREMENT COUNT	The Measurement Count field shall be a string consisting of the upper case letter “V” followed by an integer that indicates the number of data fields on each Hardware Data Record with this string as its Mnemonic Keyword.	V4	Yes
MEASUREMENT TYPE	The Measurement Type field shall be a string consisting of a series of ASCII characters representing the type of the data of each of the Measurement Fields, each optionally followed by an integer. There must be one character for each of the measurements in the Hardware Data Record containing the Mnemonic Keyword except that if the same measurement types are repeated, a single character followed by an integer representing the number of repetitions may be used. The Data type symbols shall be in the same order that the data elements associated with this Mnemonic Keyword will appear on records in strings)	I B2 F3 C	No
	Integer such as: 5 or -16 or 38676	I	

Field	Description	Examples	Mandatory
	Binary (0 or 1)	B	
	Floating Point such as: +1.53, 9.356e00, -18.6502, -6.143e-03	F	
	Character such as: Enabled or 'Not converged'	C	

4.3.7 Stop Line

4.3.7.1 The Keyword of the last line of the Metadata Section shall be "META_STOP".

4.3.7.2 There shall be no Value for the META_STOP line. This is an exception to the KVN notation.

Note: A summary of the NHM Metadata Syntax with examples is provided in Table 4-3.

Table 4-3. Summary of NHM METADATA Section Syntax

Keyword	Description	Mandatory
`META_START`	The META_START Keyword delineates the start of the NHM Metadata Section within the message. It appears on a line by itself; i.e., it shall have no equal sign or Value.	Yes
Example: `META_START`		
`COMMENT`	Comments in Metadata may appear immediately after META_START or after a Define Line in a DEFINE BLOCK. See 4.1.2.	No
Example: `COMMENT this is important`		
`TIME_SYSTEM`	The TIME_SYSTEM Keyword specifies the time system used for Timetags in the Data Section. See 4.1.3.	Yes

Examples:
`TIME_SYSTEM = UTC`
`TIME_SYSTEM = TAI`
`TIME_SYSTEM = GPS`
`TIME_SYSTEM = SCLK`		

Keyword	Description	Mandatory
OBJECT_NAME	There is no CCSDS-based restriction on the Value for this Keyword, but it is recommended to use names from the United Nations Online Registry of Objects Launched into Outer Space (Reference [8])) which includes the Object name and international designator of the participant.	Yes
Examples: OBJECT_NAME = EUTELSAT W1 OBJECT_NAME = MARS PATHFINDER OBJECT_NAME = STS106		
OBJECT_ID	Spacecraft identifier of the object corresponding to the hardware data to be given. While there is no CCSDS-based restriction on the Value for this Keyword, the names could be drawn from the United Nations Online Registry of Objects Launched into Outer Space (Reference [8])). If this is chosen, it is recommended that Values have the format YYYY-NNNP{PP}, where: – YYYY = year of launch;– NNN = three-digit serial number of launch in year YYYY (with leading zeros); – P{PP} = at least one capital letter for the identification of the part brought into space by the launch. In cases where the asset is not listed in the registry, the Value should be provided in an ICD.	Yes
Examples: OBJECT_ID = 2000-052A OBJECT_ID = 1996-068A OBJECT_ID = 2000-053A OBJECT_ID = 1996-008A		
START_TIME	The START_TIME Keyword shall specify the start time of the total time span covered by the hardware data immediately following the Metadata Section. The START_TIME Value shall be relative to the time system specified by the TIME_SYSTEM Keyword. For formatting rules see 4.3.3 and 4.3.4.	Yes
Examples: START_TIME = 1996-12-18T14:28:15.1172 START_TIME = 1996-277T07:22:54 START_TIME = 2006-001T00:00:00Z		
STOP_TIME	The STOP_TIME Keyword shall specify the stop time of the total time span covered by the hardware data immediately following this Metadata Section. The STOP_TIME Value shall be relative to the time system specified by the TIME_SYSTEM Keyword. For formatting rules see 4.1.3.	No

<table>
<tr><th>Keyword</th><th>Description</th><th>Mandatory</th></tr>
<tr><td colspan="3">Examples:
STOP_TIME = 1996-12-18T14:28:15.1172
STOP_TIME = 1996-277T07:22:54
STOP_TIME = 2006-001T00:00:00Z</td></tr>
<tr><td>DEFINE</td><td>There shall be one instance of the DEFINE Keyword in the Metadata Section for each different set of hardware data that is to be read in the Data Section. The Value associated with each DEFINE Keyword shall define a single Mnemonic Keyword that will be used in the Data Section for a single set of hardware data.</td><td>Yes (at least one)</td></tr>
<tr><td colspan="3">Examples of Define Blocks:
DEFINE = ACS.OBC1.QUAT.V5.F4C
COMMENT Onboard computed Quaternions as EME2000 inertial frame to body frame
COMMENT Floating point Quaternion Values and an onboard filter status
COMMENT Status is ‘OFF’, ‘NOT CONVERGED’, ‘CONVERGED’, or ‘EXTRAPOLATED”

DEFINE = ACS.TAM1.FIELD.V4.I3B

DEFINE = ACS.STA1.STAR1.V4.I3B
COMMENT Star tracker 1, First Star
COMMENT Horizontal and Vertical positions and Intensity in counts
COMMENT and a quality flag. Quality Flag = 0 means good data</td></tr>
<tr><td>META_STOP</td><td>The META_STOP Keyword shall delineate the end of the NHM Metadata Section within the message. It must appear on a line by itself; i.e., it shall have no parameters, Timetags or Values.</td><td>Yes</td></tr>
<tr><td colspan="3">Example:
META_STOP</td></tr>
</table>

4.4 DATA SECTION SYNTAX

4.4.1 Start Line[JH4]

4.4.1.1 The Keyword of the first line of the Data Section shall be “DATA_START”.

4.4.1.2 There shall be no Value for the DATA_START line. This is an exception to the KVN notation.

4.4.2 Comment Line

Note: Syntax for the optional Comment Line(s) is specified in Section 4.1.2.

4.4.3 Hardware Data Record

4.4.3.1 The Keyword of each Hardware Data Record shall be the Value of one of the Define Lines in the Metadata Section.

4.4.3.2 The Value of each Hardware Data Record shall consist of a Timetag followed by one or more Measurements.

4.4.3.3 The Timetag and each of the Measurements in the Value of a Hardware Data Record shall be separated from each other by one or more blank spaces.

4.4.3.4 The Timetag in each Hardware Data Record represents the time associated with the hardware measurement(s) according to the TIME_SYSTEM Keyword (see Section 4.1.3 and 4.3.4.).

4.4.3.5 The number of Measurements in each Hardware Data Record shall equal to the value of the Measurement Count Field in the Keyword of the Line.

4.4.3.6 If the Measurement Type Field exists in the Keyword of a Hardware Data Record the Content of each Measurement in that Line shall be in the format and in the order defined for each Measurement Type Field (see Section 4.3.16.6).

4.4.3.7 Measurements of type ‘C’ (Character String) may start and end with a single quotation mark character. If they do then the Character String specified by the Measurement shall include any blank space characters between the quotation marks and shall not include the quotation marks.

Note: The use of quotation marks is intended to allow blank spaces in a measurement of type ‘C’ and to distinguish these blank spaces from blank spaces that separate measurements.

4.4.4 Stop Line

4.4.4.1 The Keyword of the optional last line of the Data Section shall be “DATA_STOP”.

4.4.4.2 There shall be no Value for the DATA_STOP line. This is an exception to the KVN notation.

Note: A summary of the NHM Data Syntax with examples is provided in Table 4-4.

Table 4-4. Summary of NHM DATA Section Syntax

<table>
<tr><th>Keyword</th><th>Description</th><th>Mandatory</th></tr>
<tr><td>DATA_START</td><td>The DATA_START Keyword delineates the start of the NHM Data Section within the message. It appears on a line by itself; i.e., it shall have no equal sign or Value.</td><td>Yes</td></tr>
<tr><td colspan="3">Example:
DATA_START</td></tr>
<tr><td>A Mnemonic Keyword</td><td>The Keyword of each Hardware Data Record must be one of the Mnemonic Keywords defined in a Define Block in the Metadata Section. The Value must contain a Timetag followed by the number of measurements specified in the Value Count field of the Mnemonic Keyword. Note: Because of text wrapping single Hardware Data Records in the examples are shown as multiple lines.</td><td>Yes</td></tr>
<tr><td colspan="3">Examples:
ACS.OBC1.QUAT.V5.F4C = 2006-001T00:00:00Z 0.000407362 0.000452896
6.34934041E-05 0.999999812 ‘NOT CONVERGED’
ACS.TAM1.FIELD.V4.I3B = 2006-001T00:00:005Z 8689 6125 -203 1
ACS.OBC1.QUAT.V5.F4C = 2006-001T00:00:01Z 0.000407757 0.000452540
0.000936158 0.999999376 CONVERGED</td></tr>
<tr><td>DATA_STOP</td><td>The DATA_STOP Keyword shall delineate the end of the NHM Data Section within the message. It must appear on a line by itself; i.e., it shall have no parameters, Timetags, or Values.</td><td>No</td></tr>
<tr><td colspan="3">Example:
DATA_STOP</td></tr>
</table>

5 NHM CONTENT AND STRUCTURE IN XML

5.1 GENERAL—THE NHM/XML SCHEMA

5.1.1 This section applies only to the XML representation only.

5.1.2 The NHM/XML schema will be available on the SANA Web site. SANA is the registrar for the protocol registries created under CCSDS.

5.1.3 The NHM XML schema explicitly defines the permitted data elements and Values acceptable for the XML version of the NHM message. The location of the NHM/XML schema will be:

http://sanaregistry.org/r/ndmxml/ndmxml-1.0-nhm-1.0.xsd

5.1.4 Where possible this schema uses simple types and complex types used by the constituent schemas that make up Navigation Data Messages (see Reference [7]).

5.2 NHM/XML BASIC STRUCTURE

5.2.1 Each NHM shall consist of a <header> and a <body>.

5.2.2 The NHM <body> shall consist of a single <segment> construct.

5.2.3 The NHM <segment> shall consist of a <metadata>/<data> pair, as shown in Figure 5-1.

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

Figure 5-1. NHM XML Basic Structure

5.3 NHM/XML TAGS

5.3.1 An NHM XML tag shall be all uppercase if it corresponds directly to a KVN Keyword from the Header or Metadata Section.

5.3.2 There is an exception where there is not a strict correspondence between Keywords in the KVN and tags in the XML implementations, specifically, the 'CCSDS_NHM_VERS' Keyword from the NHM Header. The 'CCSDS_NHM_VERS' Keyword and its Value shall appear as XML attributes rather than an XML element.

5.3.3 NHM XML tag names for the NHM Data Section shall have a special structure noted below due to the way in which the Mnemonic Keywords are dynamically constructed (see Section 4).

5.3.4 NHM XML tags related to the XML message structure (i.e., that do not correspond directly to a KVN Keyword) shall be in 'lowerCamelCase' (e.g., <defineBlock>,<header>, <segment>, etc.).

5.4 CONSTRUCTING AN NHM/XML INSTANCE

5.4.1 OVERVIEW

This subsection provides more detailed instructions for the user on how to create an XML message based on the ASCII-text KVN-formatted message described in Sections 3 and 4.

5.4.2 XML VERSION

5.4.2.1 The first line in the instantiation shall specify the XML version:

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

This line must appear on the first line of each instantiation, exactly as shown.

5.4.3 BEGINNING THE INSTANTIATION: ROOT DATA ELEMENT

5.4.3.1 An NHM instantiation shall be delimited with the <nhm></nhm> root element tags using the standard attributes documented in Reference [7].

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

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

5.4.3.3 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 length of the Value associated with the xsi:noNamespaceSchemaLocation attribute can cause the string to wrap to a new line; however, the string itself contains no breaks.

5.4.3.4 For use in a local operations environment, the NDM/XML schema set (which includes the NHM schema) may be downloaded from the SANA web site to a local server that meets local requirements for operations robustness. See reference [**7**].

5.4.3.5 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.

5.4.3.6 The final attributes of the <nhm> tag shall be 'id' and 'version'.

5.4.3.7 The 'id' attribute shall be 'id="CCSDS_NHM_VERS"'. The 'version' attribute shall be 'version="1.0"'.

NOTE – The following example root element tag for an NHM instantiation combines all the directions in the preceding several subsections:

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

5.4.4 THE NHM/XML HEADER SECTION

5.4.4.1 The NHM Header shall have a standard Header format, with tags <header> and </header>.

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

5.4.4.3 The standard NHM Header shall contain the following element tags:

a) <CREATION_DATE>

b) <ORIGINATOR>

NOTE – The rules for these Keywords are specified in Table 4-1. A completed Header would look like this:

```
<header>
  <COMMENT>Some comment string.</COMMENT>
  <CREATION_DATE>2010-03-12T22:31:12.000</CREATION_DATE>
  <ORIGINATOR>NASA</ORIGINATOR>
</header>
```

5.4.5 THE NHM/XML BODY SECTION

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

5.4.5.2 Inside the <body></body> tag pair must appear one <segment></segment> tag pair.

NOTE – In essence, the segment tag in the NHM XML implementation is not strictly necessary, however, it is necessary for structural symmetry with the overall NDM/XML paradigm (see Reference [7]).

5.4.5.3 The <segment> must be made up of one <metadata></metadata> tag pair and one <data></data> tag pair.

5.4.6 THE NHM/XML METADATA SECTION

5.4.6.1 The Metadata Section shall be set off by the <metadata></metadata> tag combination.

5.4.6.2 Between the <metadata> and </metadata> tags, the Keywords shall be those specified in Table 4-3 with the exception of the META_START and META_STOP Keywords.

5.4.6.3

Each NHM/XML Metadata Section shall include at least one <defineBlock></defineBlock> construct which is used to provide a set of descriptive information about an instrument in the Data Section.

5.4.6.4 The <defineBlock> shall consist of a required DEFINE Keyword, and one or more optional comment statements as follows:

```
<defineBlock>
   <DEFINE>Mnemonic Keyword here</DEFINE>
   <COMMENT>...</COMMENT>
</defineBlock>
```

NOTE – The text “Mnemonic Keyword Here” is a placeholder to be replaced by an actual Mnemonic Keyword. The syntax of Mnemonic Keywords is specified in Table 4-2. Any text may appear in the comment statement as in KVN notation described in Section 4.1.2.

5.4.7 THE NHM DATA SECTION

5.4.7.1 The Data Section shall follow the Metadata Section and shall be set off by the <data></data> tag combination.

5.4.7.2 Between the <data> and </data> tags, the Keywords shall be the mnemonics defined in the Metadata section.

5.4.7.3 Each NHM/XML Data Section shall include at least one <hardwareDataRecord></hardwareDataRecord> construct which is used to provide a set of measurements from one of the instruments defined in the Metadata Section. This construct is shown in Figure 5-1.

5.4.8 SPECIAL NHM/XML TAGS

5.4.8.1 Special tags shall be used to encapsulate the information in the XML implementation of the NHM that are not necessary in the KVN implementation.

5.4.8.2 The special tags indicating logical block divisions shall be those defined in Table 5-1.

Table 5-1 Special NHM/XML Tags

Special Tag	Definition
`<defineBlock>`	Delineates the definition of a Mnemonic Keyword
`<hardwareDataRecord>`	Distinguishes one Hardware Data Record from the next.
`<keyword>`	Contains one of the Mnemonic Keywords created using a Define Block in the metadata, in particular, the one associated with the measurements in a given Hardware Data Record.
`<timetag>`	Contains the Timetag of the particular measurement(s) in the Hardware Data Record
`<measurement>`	Contains a number received from telemetry data.

1. Basic structure of a Hardware Data Record in the Data Section:

```
<hardwareDataRecord>
      <keyword></keyword>
      <timetag></timetag>
      <measurement></measurement>
      <measurement></measurement>
                   .
                   .
                   .
      <measurement></measurement>
</hardwareDataRecord>
```

2. Three sample NHM Hardware Data Records in KVN:

```
THM.IRU1.TEMPV.V7.F6B = 2011-10-28T20:15:34.4Z 3.41 4.05 1.32 3.98 5.79 5.11 0
ACS.IRU1.RATES.V4.I3B = 2011-10-28T20:15:34.6Z 18312 191 57637 0
ACS.STA1.STAR1.V4.I3B = 2011-10-28T20:15:34.7Z 12778 -4069 82 0
```

3. The KVN sample NHM Hardware Data Records converted to XML:

```
<hardwareDataRecord>
      <keyword>THM.IRU1.TEMPV.V7.F6B</keyword>
      <timetag>2011-10-28T20:15:34.4Z</timetag>
      <measurement>3.41</measurement>
      <measurement>4.05</measurement>
      <measurement>1.32</measurement>
      <measurement>3.98</measurement>
      <measurement>5.79</measurement>
      <measurement>5.11</measurement>
      <measurement>0</measurement>
</hardwareDataRecord>

<hardwareDataRecord>
      <keyword>ACS.IRU1.RATES.V4.I3B</keyword>
      <timetag>2011-10-28T20:15:34.6Z</timetag>
      <measurement>18312</measurement>
      <measurement>191</measurement>
      <measurement>57637</measurement>
      <measurement>0</measurement>
</hardwareDataRecord>

<hardwareDataRecord>
      <keyword>ACS.STA1.STAR1.V4.I3B</keyword>
      <timetag>2011-10-28T20:15:34.7Z</timetag>
      <measurement>12778</measurement>
      <measurement>-4069</measurement>
      <measurement>82</measurement>
      <measurement>0</measurement>
</hardwareDataRecord>
```

Figure 5-2. NHM XML Data Section Basic Structure/Correspondence to KVN Data

5.5 LOCAL OPERATIONS

5.5.1 For use in a local operations environment, the NDM/XML schema set (which includes the NHM schema) may be downloaded from the SANA web site to a local server that meets local requirements for operations robustness. See reference [**7**].

5.5.2 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.

6 NAVIGATION HARDWARE MESSAGE XML SYNTAX

6.1 OVERVIEW

XML instantiations of an NHM shall observe the syntax described in this chapter.

6.2 NHM LINES IN XML

6.2.1 Each NHM file shall consist of a set of NHM lines. Each NHM line shall be one of the following:

- XML version line;
- an XML-formatted line; or
- a blank line.

6.2.2 Each NHM line must not exceed 254 ASCII characters and spaces (excluding line termination character[s]).

6.2.3 Only printable ASCII characters and blanks shall be used. Control characters (such as TAB, etc.) shall not be used, with the exception of the line termination characters specified below.

6.2.4 Blank lines may be used at any position within the file. Blank lines shall have no assignable meaning, and may be ignored.

6.2.5 All lines shall be terminated by a single Carriage Return or a single Line Feed, or a Carriage Return/Line Feed pair or a Line Feed/Carriage Return pair.

6.3 NHM VALUES IN XML

6.3.1 Each Mandatory XML tag must be present and contain a valid Value.

6.3.2 Integer Values shall follow the conventions of the integer data type per Reference [2]. Additional restrictions on the allowable range of Values permitted for any integer data element may also be defined in the NHM XML Schema.

NOTE – Examples of such restrictions may include a defined range (e.g., 0 - 100, 1 - 10, etc.), a set of enumerated Values (e.g., 0,1,2,4,8), a pre-defined specific variation such as positiveInteger, or a user-defined data type variation.

6.3.3 Non-integer numeric Values may be expressed in either fixed-point or floating-point notation. Numeric Values shall follow the conventions of the double data type per Reference [2]. Additional restrictions on the allowable range of Values permitted for any numeric data element may also be defined in the NHM XML Schema.

NOTE – Examples of such restrictions may include a defined range (e.g., 0.0-100.0, etc.), or a user-defined data type variation.

6.3.4 Text Value data shall follow the conventions of the string data type per Reference [2]. Additional restrictions on the allowable range of Values permitted for any data element may also be defined in the NHM XML Schema.

NOTE – Examples of such restrictions may include a set of enumerated Values (e.g., ‘YES’/‘NO’) or other user-defined data type variation.

6.3.5 Except for Text Value data (6.3.4), Text Values in NHM/XML instantiations (i.e., the Values between the opening and closing tags), shall consist of either all uppercase or all lowercase characters; an exception is made for Values between the <COMMENT> and </COMMENT> tags, which may be in any case desired by the user. Otherwise, mixing of uppercase and lowercase characters is prohibited.[JH5]

6.3.6 In Value fields that represent a Timetag, Values shall follow the conventions of the ndm**:** epochType data type used in all CCSDS NDM/XML schemas.

6.4 NHM UNITS IN XML

6.4.1 Units are not explicitly displayed in the NHM. The units associated with Values in the NHM must be defined in an ICD.

6.5 NHM COMMENTS IN XML

Comments are optional and must be displayed as Values between the <COMMENT> and </COMMENT> tags. Comments may be in any case desired by the user.

ANNEX A.

IMPLEMENTATION CONFORMANCE STATEMENT PRO FORMA

(NORMATIVE)

A.1 INTRODUCTION

A1.1 OVERVIEW

This annex provides the Implementation Conformance Statement (ICS) Requirements List (RL) for an implementation of an NHM (CCSDS 510.0). The ICS for an implementation is generated by completing the RL in accordance with the instructions below. An implementation shall satisfy the mandatory conformance requirements referenced in the RL.

– The RL in this annex is blank. An implementation's completed RL is called the ICS. The ICS states which capabilities and options have been implemented. The following can use the ICS:
– the implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight;
– a supplier or potential acquirer of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard ICS pro forma;
– a user or potential user of the implementation, as a basis for initially checking the possibility of interworking with another implementation (it should be noted that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible ICSes);
– a tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A1.2 ABBREVIATIONS AND CONVENTIONS

The RL consists of information in tabular form. The status of features is indicated using the abbreviations and conventions described below.

<u>Item Column</u>

The item column contains sequential numbers for items in the table.

<u>Feature Column</u>

The feature column contains a brief descriptive name for a feature. It implicitly means 'Is this feature supported by the implementation?'

NOTE – The features itemized in the RL are elements of an NHM. Therefore support for a mandatory feature indicates that generated messages will include that feature, and support for an optional feature indicates that generated messages can include that feature.

Keyword Column

The Keyword column contains, where applicable, the NHM Keyword associated with the feature.

Reference Column

The reference column indicates the relevant subsection or table in NHM (CCSDS 510.0) (this document).

Status Column

The status column uses the following notations:

M mandatory.

O optional.

Support Column Symbols

The support column is to be used by the implementer to state whether a feature is supported by entering Y, N, or N/A, indicating:

Y Yes, supported by the implementation.

N No, not supported by the implementation.

N/A Not applicable.

A1.3 INSTRUCTIONS FOR COMPLETING THE RL

An implementer shows the extent of compliance to the Recommended Standard by completing the RL; that is, the state of compliance with all mandatory requirements and the options supported are shown. The resulting completed RL is called an ICS. The implementer shall complete the RL by entering appropriate responses in the support or Values supported column, using the notation described in A1.2. If a conditional requirement is inapplicable, N/A should be used. If a mandatory requirement is not satisfied, exception information must be supplied by entering a reference Xi, where i is a unique identifier, to an accompanying rationale for the noncompliance.

A2 ICS PRO FORMA FOR NAVIGATION HARDWARE DATA MESSAGE

A2.1 GENERAL INFORMATION

A2.1.1 Identification of ICS

Date of Statement (DD/MM/YYYY)	
ICS serial number	
System Conformance statement cross-reference	

A2.1.2 Identification of Implementation Under Test (IUT)

Implementation name	
Implementation version	
Special Configuration	
Other Information	

A2.1.3 Identification of Supplier

Supplier	
Contact Point for Queries	
Implementation Name(s) and Versions	
Other information necessary for full identification, e.g., name(s) and version(s) for machines and/or operating systems; System Name(s)	

A2.1.4 Document Version

CCSDS 510.0 Document Version	
Have any exceptions been required? (Note: A YES answer means that the implementation does not conform to the Recommended Standard. Non-supported mandatory capabilities are to be identified in the ICS, with an explanation of why the implementation is non-conforming.)	Yes _____ No_____

A2.1.5 Requirements List

Item	Feature	Keyword	Reference	Status	Support
1	NHM Header	N/A		M	
1.1	NHM Version	CCSDS_NHM_VERS		M	
1.2	Comment	COMMENT		O	
1.3	Creation Date	CREATION_DATE		M	
1.4	Originator	ORIGINATOR		M	
1.5	Header Line Order	N/A		M	
2	NHM Metadata	N/A		M	
2.1	Start	META_START		M	
2.2	Comment	COMMENT		O	
2.3	Time System	TIME_SYSTEM		M	
2.4	Spacecraft Name	OBJECT_NAME		M	
2.5	Spacecraft ID	OBJECT_ID		M	
2.6	Start time of data	START_TIME		M	
2.7	Stop time of data	STOP_TIME		O	
2.8	Define Block	N/A		M	
2.8.1	Define Line	DEFINE		M	
2.8.1.1	Mnemonic Keyword	N/A		M	
2.8.1.2	System Field	N/A		M	
2.8.1.2	Hardware Type Field	N/A		M	
2.8.1.3	Data Group Field	N/A		M	
2.8.1.4	Measurement Count Field	N/A		M	
2.8.1.5	Measurement Type Field	N/A		O	
2.8.2	Comments	COMMENT		O	
2.9	Metadata Order	N/A		M	
2.10	Metadata stop	META_STOP		M	
3	NHM Data	N/A		M	
3.1	Data Start	DATA_START		M	
3.2	Comment	COMMENT		O	
3.3	Hardware Data Records	Keyword must be one of those defined in a Define Block in the Metadata		M	
3.4	Data Stop	DATA_STOP		M	

ANNEX B.

VALUES FOR THE TIME_SYSTEM KEYWORD

(NORMATIVE)

The Values in this annex represent the set of acceptable Values for the TIME_SYSTEM Keyword. For details and description of these time systems, see Reference H2. If exchange partners wish to use different settings, they should be documented in the ICD.

Table B-2: Normative Values for TIME_SYSTEM Metadata Keyword

Time System Value	Meaning
GMST	Greenwich Mean Sidereal Time
GPS	Global Positioning System
MET	Mission Elapsed Time
	Note: Mission Elapsed time is the time in normal time units since the mission start.
SCLK	Spacecraft Clock
	Note: Spacecraft Clock time is the number of counts that have occurred on a spacecraft clock (with each count representing a specific time increment) since the clock was last reset. Before use, Spacecraft Clock times must be converted into a universally usable time system but, since the spacecraft sometime tags data with internal Spacecraft Clock times it may occur in the NHM. Information concerning the use of the Spacecraft Clock should be included in an ICD.
SYSTIME	System Time
	System time, measured in elapsed seconds from UTC midnight (00:00 Z) on a particular day.
TAI	International Atomic Time
TT	Terrestrial Time
UT1	Universal Time
UTC	Coordinated Universal Time

ANNEX C.

SECURITY, SANA AND PATENT CONSIDERATIONS

(INFORMATIVE)

C 1 SECURITY CONSIDERATIONS

C1.1 ANALYSIS OF SECURITY CONSIDERATIONS

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

C1.2 CONSEQUENCES OF NOT APPLYING SECURITY TO THE TECHNOLOGY

The consequences of not applying security to the systems and networks on which this Proposed Standard is implemented could include potential loss, corruption, and theft of data. Because these messages are used in orbit determination and attitude determination, the consequences of not applying security to the systems and networks on which this Proposed Standard is implemented could include compromise or loss of the mission if malicious tampering of a particularly severe nature occurs.

C1.3 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 Proposed Standard. It is strongly recommended that potential threats or attack scenarios applicable to the systems and networks on which this Proposed Standard is implemented be addressed by the management of those systems and networks.

C1.4 DATA PRIVACY

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

C1.5 DATA INTEGRITY

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

C1.6 AUTHENTICATION OF COMMUNICATING ENTITIES

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

C1.7 DATA TRANSFER BETWEEN COMMUNICATING ENTITIES

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

C1.8 CONTROL OF ACCESS TO RESOURCES

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

C1.9 AUDITING OF RESOURCE USAGE

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

C1.10 UNAUTHORIZED ACCESS

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

C1.11 DATA SECURITY IMPLEMENTATION SPECIFICS

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

C2 SANA CONSIDERATIONS

The following NHM-related items will be registered with the SANA operator. Requests to add information to any of the registries should be sent to "info@sanaregistry.org. The registration rule for new entries in the registry is that new requests will be considered by the CCSDS Area or Working Group responsible for the maintenance of the NHM at the time of the request.

C2.1 XML SCHEMA

The NHM XML schema will be registered with the SANA. New requests for this registry should be sent to SANA (mailto:info@sanaregistry.org). See http://sanaregistry.org/r/ndmxml_qualified/ndmxml_qualified.html

C2.2 HARDWARE TYPES AND UNITS

Approved Values for the Mnemonic Keyword System Field, and Hardware Type Field will be registered with SANA. New requests for this registry should be sent to SANA (mailto:info@sanaregistry.org).

Note: See Table D-1 for examples.

C3 PATENT CONSIDERATIONS

The recommendations of this document have no patent issues.

ANNEX D.

VALUES FOR DEFINE KEYWORD

(INFORMATIVE)

The Values in this annex represent examples of Values associated with three fields of the Mnemonic Keywords defined in the records of the Metadata Section with the DEFINE Keyword. The complete list of normative Values will be contained in the SANA registry http://sanaregistry.org/r/nhm_define_keyword_values/nhm_define_keyword_values.

An example of this table in the SANA registry is given as Table D-1 below.

Each entry (row) of the table contains the following columns:

The “Value” column contains Values that would appear in the SANA registry table.

The “Mnemonic Keyword Field “ column identifies values for the System and Hardware Type fields in the Mnemonic Keyword. The different types of fields are:

1. System: Entries marked “System Field” contain the Values that will be used in the System Field of a Mnemonic Keyword defined with the Define line in the Metadata section. It indicates the spacecraft system concerned with the data on Hardware Data Records in the Data Section. Because different spacecraft systems may be concerned with the same hardware, the same data (in different messages) may be associated with different systems, depending on the intended use of the message.
2. Hardware: Entries marked “Hardware Type” indicate the particular spacecraft hardware associated with particular data. The Values of Hardware Types will appear in the Hardware Type Field of a Mnemonic Keyword defined with the Define line in the Metadata section. Since there are often several instances of a particular type of hardware on a spacecraft the Hardware Type Field in the Mnemonic Keyword will also include a numeric designator of the instance of the hardware. Some “Hardware Types” do not correspond to actual hardware but represent combinations of processed hardware data such as output from the Onboard Computer (Type is “OBC”).

The “Meaning” column of Table D-1 contains a brief description of the significance of the Measurement.

The “Description” column of Table D-1 shows (where relevant) the type of physical quantity represented by the measurement or other information on the use of the Measurement Field.

The “Examples of Units” column of Table D-1 shows typical units in which Measurements of a particular type are represented. Because spacecraft instrument units are often instrument specific, even for hardware that perform similar functions, an ICD should be used to specify which of the units are used in any message.

Mnemonic Keyword Field	Value	Meaning	Description	Examples of Units
System Field	ACS	Attitude Control System (Attitude Determination and Control)		
	CDH	Command and Data Handling System		
	COM	Communications		
	NAV	Navigation		
	PWR	Power		
	PRP	Propulsion		
	THM	Thermal		
Hardware Type	ACC	Accelerometer	accelerations	m/s^2
	ANT	Antenna	Receiver Power	dB
			Gimbal Angles	counts, deg, rad
	AST	Autonomous Star Tracker	star tracker attitude	no units
	CSS	Coarse Sun Sensor	angle from Sun	counts, mA, deg, rad
	DSS	Digital Sun Sensor	Sun position	counts, deg, rad
	GNS	Global Navigation System Receiver	pseudorange to GNSS	km, m
			satellite position	km, m
			satellite velocity	km/s, m/s
	IRU	Inertial Reference Unit	attitude rates	deg/s, rad/s, arcsec/s
			accumulated angles	counts, deg, rad
	OBC	On Board Computed	Any Values that are computed onboard from hardware data such as attitude, position, velocity, etc	Various
	STA	Star Tracker	star direction	counts, deg, rad
			star intensity	magnitude units
	THR	Thruster	pulse count	counts
			tank pressure	Pa

Table D- 1 Examples of Values in SANA Registry

ANNEX E.

EXAMPLE NAVIGATION HARDWARE MESSAGE MNEMONIC KEYWORDS WITH CORRESPONDING ICD INFORMATION

(INFORMATIVE)

Table E-1: Example of Information Used in Creating an NHM that Should Be Included in an ICD

Mnemonic Keyword	Information in ICD	Needed for Processing
`ACS.CSS1.EYECURRENT.V5.I4B`	Definitions of "eyecurrent"	Yes
	Conversion factors for converting counts to engineering units	No
	Mounting vector for each of the four eyes	No
	Definition of Binary flag	Yes
`THM.AST1.TEMP.V3`	Definition of TEMP	Yes
	Conversion of Values to temperatures	Yes
	Location of sensors	No
`ACS.OBC1.QUAT.V5.F4B`	Definition of QUAT including relevant frames, rotation directions, and the identity of the scalar component.	Yes
	Definition of Binary flag	Yes

<u>Explanation of ACS.CSS1.EYECURRENT.V5.I4B</u>

The data associated with this Mnemonic Keyword in this example is associated with Coarse Sun Sensor 1 (CSS1). CSS1 consists of 4 photocells each of which reports a current that is related to the angle between the eye normal and the Sun direction. The currents are transmitted in counts. The usable processed data from CSS1 is the Sun direction in the body frame. In order to obtain this direction the counts must first be converted to currents and the currents then converted to angles from the corresponding eye normal directions. These angles, together with the eye normal directions in the body frame can be used to determine the Sun direction in the body frame. The binary Quality Flag distinguishes between Valid and Invalid measurements (0 = valid data, 1 = invalid data).

Explanation of THM.AST1.TEMP.V3

The data associated with this Mnemonic Keyword consists of temperature readings at three locations on AST1. Each reading is transmitted as a voltage and a conversion from volts to degrees C is needed for their use. The location of each temperature sensor (e.g. instrument lens, instrument body, instrument photocell) is useful for analysis but is not required for processing.

Explanation of ACS.OBC1.QUAT.V5.F4B

The data associated with this Mnemonic Keyword consists of quaternions computed by the onboard computer, using data from attitude sensors. It is the onboard estimate of the attitude. It specifies the rotation of one frame relative to another (typically a body frame relative to an inertial frame). The binary Quality Flag distinguishes between Valid and Invalid measurements (1 = valid data, 0 = invalid data).

ANNEX F.

EXAMPLE NAVIGATION HARDWARE MESSAGES

(INFORMATIVE)

```
CCSDS_NHM_VERS = 1.0
COMMENT This is fictitious data for a very simple spacecraft
CREATION_DATE = 2012-11-27T09:55:31
ORIGINATOR = NASA

META_START
TIME_SYSTEM = UTC
OBJECT_NAME = STS106
OBJECT_ID = 2000-053A
START_TIME = 2009-06-29T0 T07:14:50.6Z
DEFINE = ACS.TAM1.FIELD.V4.I3B
COMMENT Three axis magnetometer detected field in counts and a quality flag
COMMENT Three axis magnetometer data is expressed in the TAM1 Frame (see ICD)
COMMENT Three axis magnetometer data is in counts that may be converted to milligauss by a linear transfer function
DEFINE = ACS.STA1.STAR1.V4.I3B
COMMENT Star tracker 1, First Star.  Horizontal and Vertical positions and Intensity in counts and a quality flag
DEFINE = ACS.STA1.STAR2.V4.I3B
COMMENT Star tracker 1, Second Star.  Horizontal and Vertical positions and Intensity in counts and a quality flag
DEFINE = ACS.STA2.STAR1.V4.I3B
COMMENT Star tracker 2, First Star.  Horizontal and Vertical positions and Intensity in counts and a quality flag
DEFINE = ACS.STA2.STAR2.V4.I3B
COMMENT Star tracker 2, Second Star.  Horizontal and Vertical positions and Intensity in counts and a quality flag
DEFINE = ACS.IRU1.RATES.V4.I3B
COMMENT Gyro rates for IRU assembly-1 3 axes in counts and a quality flag in the Body Frame
DEFINE = THM.IRU1.TEMPV.V7.F6B
COMMENT IRU temperatures are often unavailable and may not exist in this data set
DEFINE = ACS.OBC1.QUAT.V5.F4B
COMMENT Onboard computed Quaternions as EME2000 inertial frame to body frame and a quality flag
META_STOP
DATA_START
COMMENT The data Values are not real in this example
ACS.IRU1.RATES.V4.I3B =  2009-06-29T07:15:00.6Z 18312 191 57637 0
ACS.STA1.STAR1.V4.I3B =  2009-06-29T07:15:00.7Z 12778 -4069 82 0
ACS.STA1.STAR2.V4.I3B =  2009-06-29T07:15:00.7Z 9200 4565 81 0
ACS.IRU1.RATES.V4.I3B =  2009-06-29T07:15:01.0Z 18767 29 57295 0
ACS.STA2.STAR1.V4.I3B =  2009-06-29T07:15:01.1Z 4495 4834 78 0
ACS.STA2.STAR2.V4.I3B =  2009-06-29T07:15:01.1Z 27180 6367 89 0
ACS.OBC1.QUAT.V5.F4B =  2009-06-29T07:15:01.4Z 0.8619094 0.5002867 0.0472852 0.0677461 0
ACS.IRU1.RATES.V4.I3B =  2009-06-29T07:15:01.6Z 18704 64126 56639 0
ACS.STA2.STAR1.V4.I3B =  2009-06-29T07:15:01.9Z 4663 5257 78 0
```

```
ACS.STA2.STAR2.V4.I3B =  2009-06-29T07:15:01.9Z 25079 6678 89 0
ACS.TAM1.FIELD.V4.I3B =  2009-06-29T07:15:02.6Z 5527 -1596 -21298 0
DATA_STOP
```

ANNEX G.

NHM EXAMPLE IN XML FORMAT

(INFORMATIVE)

The following is a sample of an NHM in XML format. Note that some of the lines wrap in this representation, but would not wrap in an actual NHM file given the 254 character line length.


```
<?xml version="1.0" encoding="UTF-8"?>
<nhm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="http://sanaregistry.org/r/ndmxml/ndmxml-1.0-
master.xsd" id="CCSDS_NHM_VERS" version="1.0">
   <header>
      <COMMENT>This is NHM Annex F KVN example expressed in XML</COMMENT>
      <COMMENT>This is fictitious data for a very simple spacecraft</COMMENT>
      <CREATION_DATE>2012-11-27T09:55:31</CREATION_DATE>
      <ORIGINATOR>NASA</ORIGINATOR>
   </header>
   <body>
      &lt;segment&gt;
         <metadata>
            <TIME_SYSTEM>UTC</TIME_SYSTEM>
            <OBJECT_NAME>STS106</OBJECT_NAME>
            <OBJECT_ID>2000-053A</OBJECT_ID>
            <START_TIME>2009-06-29T07:15:00.6Z</START_TIME>
            <defineBlock>
               <DEFINE>ACS.TAM1.FIELD.V4.I3B</DEFINE>
               <COMMENT>Three axis magnetometer detected field in counts and a
quality flag</COMMENT>
               <COMMENT>Three axis magnetometer data is expressed in the TAM1
Frame (see ICD)</COMMENT>
               <COMMENT>Three axis magnetometer data is in counts that may be
converted to milligauss by a linear transfer function</COMMENT>
            </defineBlock>
            <defineBlock>
               <DEFINE>ACS.STA1.STAR1.V4.I3B</DEFINE>
               <COMMENT>Star tracker 1, First Star.  Horizontal and Vertical
positions and Intensity in counts and a quality flag</COMMENT>
```

```
            </defineBlock>
            <defineBlock>
               <DEFINE>ACS.STA1.STAR2.V4.I3B</DEFINE>
               <COMMENT>Star tracker 1, Second Star.  Horizontal and Vertical
positions and Intensity in counts and a quality flag</COMMENT>
            </defineBlock>
            <defineBlock>
               <DEFINE>ACS.IRU1.RATES.V4.I3B</DEFINE>
               <COMMENT>Gyro rates for IRU assembly-1 3 axes in counts and a
quality flag in the Body Frame</COMMENT>
            </defineBlock>
            <defineBlock>
               <DEFINE>THM.IRU1.TEMPV.V7.F6B</DEFINE>
            </defineBlock>
            <defineBlock>
               <DEFINE>ACS.OBC1.QUAT.V5.F4B</DEFINE>
               <COMMENT>Onboard computed Quaternions as EME2000 inertial frame
to body frame and a quality flag</COMMENT>
            </defineBlock>
         </metadata>
         <data>
            <COMMENT>The data Values are not real in this example</COMMENT>
            <hardwareDataRecord>
               <keyword>ACS.IRU1.RATES.V4.I3B</keyword>
               <timetag>2009-06-29T07:15:00.6Z</timetag>
               <measurement>18312</measurement>
               <measurement>191</measurement>
               <measurement>57637</measurement>
               <measurement>0</measurement>
            </hardwareDataRecord>
            <hardwareDataRecord>
               <keyword>ACS.STA1.STAR1.V4.I3B</keyword>
               <timetag>2009-06-29T07:15:00.7Z</timetag>
               <measurement>12778</measurement>
               <measurement>-4069</measurement>
               <measurement>82</measurement>
               <measurement>0</measurement>
            </hardwareDataRecord>
            <hardwareDataRecord>
               <keyword>ACS.STA1.STAR2.V4.I3B</keyword>
               <timetag>2009-06-29T07:15:00.7Z</timetag>
```

```
        <measurement>9200</measurement>
        <measurement>4565</measurement>
        <measurement>81</measurement>
        <measurement>0</measurement>
    </hardwareDataRecord>
    <hardwareDataRecord>
        <keyword>ACS.IRU1.RATES.V4.I3B</keyword>
        <timetag>2009-06-29T07:15:01.0Z</timetag>
        <measurement>18767</measurement>
        <measurement>29</measurement>
        <measurement>57295</measurement>
        <measurement>0</measurement>
    </hardwareDataRecord>
    <hardwareDataRecord>
        <keyword>ACS.STA1.STAR1.V4.I3B</keyword>
        <timetag>2009-06-29T07:15:01.1Z</timetag>
        <measurement>4495</measurement>
        <measurement>4834</measurement>
        <measurement>78</measurement>
        <measurement>0</measurement>
    </hardwareDataRecord>
    <hardwareDataRecord>
        <keyword>ACS.STA1.STAR2.V4.I3B</keyword>
        <timetag>2009-06-29T07:15:01.1Z</timetag>
        <measurement>27180</measurement>
        <measurement>6367</measurement>
        <measurement>89</measurement>
        <measurement>0</measurement>
    </hardwareDataRecord>
    <hardwareDataRecord>
        <keyword>ACS.OBC1.QUAT.V5.F4B</keyword>
        <timetag>2009-06-29T07:15:01.4Z</timetag>
        <measurement>0.8619094</measurement>
        <measurement>0.5002867</measurement>
        <measurement>0.0472852</measurement>
        <measurement>0.0677461</measurement>
        <measurement>0</measurement>
    </hardwareDataRecord>
    <hardwareDataRecord>
        <keyword>ACS.IRU1.RATES.V4.I3B</keyword>
```

```
            <timetag>2009-06-29T07:15:01.6Z</timetag>
            <measurement>18704</measurement>
            <measurement>64126</measurement>
            <measurement>56639</measurement>
            <measurement>0</measurement>
         </hardwareDataRecord>
         <hardwareDataRecord>
            <keyword>ACS.STA1.STAR1.V4.I3B</keyword>
            <timetag>2009-06-29T07:15:01.9Z</timetag>
            <measurement>4663</measurement>
            <measurement>5257</measurement>
            <measurement>78</measurement>
            <measurement>0</measurement>
         </hardwareDataRecord>
         <hardwareDataRecord>
            <keyword>ACS.STA1.STAR2.V4.I3B</keyword>
            <timetag>2009-06-29T07:15:01.9Z</timetag>
            <measurement>25079</measurement>
            <measurement>6678</measurement>
            <measurement>89</measurement>
            <measurement>0</measurement>
         </hardwareDataRecord>
         <hardwareDataRecord>
            <keyword>ACS.TAM1.FIELD.V4.I3B</keyword>
            <timetag>2009-06-29T07:15:02.6Z</timetag>
            <measurement>5527</measurement>
            <measurement>-1596</measurement>
            <measurement>-21298</measurement>
            <measurement>0</measurement>
         </hardwareDataRecord>
      </data>
   &lt;/segment&gt;
 </body>
</nhm>
```

ANNEX H.

INFORMATIVE REFERENCES

(INFORMATIVE)

NOTE – Normative References are provided in section 1.7.

[H1] *Organization and Processes for the Consultative Committee for Space Data Systems*. CCSDS A02.1-Y-4. Yellow Book. Issue 4. Washington, D.C.: CCSDS, April 2014.

[H2] *Navigation Data—Definitions and Conventions*. Report Concerning Space Data System Standards, CCSDS 500.0-G-3. Green Book. Issue 3. Washington, D.C.: CCSDS, May 2010.

[H3] Astrodynamics – *Propagation Specifications, Technical Definitions, and Recommended Practices*, ANSI/AIAA S-131-2010, Reston, VA: American Institute of Aeronautics and Astronautics, 2010, http://astrodynamicstandards.com/Resources/ANSI_AIAA_S-131-2010.pdf

ANNEX I.

NAVIGATION HARDWARE MESSAGE GOALS AND REQUIREMENTS

(INFORMATIVE)

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

- Primary Requirements: These are the most elementary and necessary requirements. They would exist no matter the context in which the CCSDS is operating, i.e., regardless of pre-existing conditions within the CCSDS, its Member Agencies, or other independent users.
- Desirable Characteristics: These are not requirements, but they are felt to be important or useful features of the Recommended Standard.

Table I-1. Primary Requirements

ID	Requirement	Rationale	Trace
NHM-P01	The NHM data shall be provided in digital form (computer file or stream).	Facilitates computerized processing of NHMs	3.1.5
NHM-P02	The NHM shall be provided in data structures that are readily ported between, and useable within, 'all' computing environments in use by Member Agencies.	The CCSDS objective of promoting interoperability is not met if messages are produced using esoteric or proprietary data structures.	3.1.1
NHM-P03	The NHM shall provide a mechanism by which messages may be uniquely identified and clearly annotated. The file name alone is considered insufficient for this purpose.	Facilitates discussion between a message recipient and the originator should it become necessary.	3.2
NHM-P04	The NHM shall provide time measurements (time stamps, or epochs) in commonly used, clearly specified systems.	The CCSDS objective of promoting interoperability is not met if time measurements are produced in esoteric or proprietary time systems	3.3.2 b, Annex B

ID	Requirement	Rationale	Trace
NHM-P05	The NHM shall be provided in, or shall include, an ASCII format.	ASCII character-based messages promote interoperability. ASCII messages are useful in transferring data between heterogeneous computing systems, because the ASCII character set is nearly universally used and is interpretable by all popular systems. In addition, direct human-readable dumps of text to displays, emails, documents or printers are possible without preprocessing.	3.1.1, 6.2.2, 6.2.3
NHM-P06	The NHM shall not require software supplied by other Agencies.	This principle was agreed upon early in the history of the CCSDS Navigation Working Group.	n/a
NHM-P07	The NHM shall provide data for a single spacecraft.	Data from multiple spacecraft would be confusing and the specific hardware from which the data arises will be on a single spacecraft.	3.3.2 c
NHM-P08	The single spacecraft to which an NHM applies shall be clearly identified.	In order to be useful to an operations team, it is necessary to know the spacecraft from which the data originated.	3.3.2 c and d
NHM-P09	The source (hardware) from which data in lines in the NHM Data Section originate shall be clearly identified.	In order to be useful to an operations team, it is necessary to know the subsystem and hardware from which the data originated.	3.3.4, 4.3.16
NHM-P10	The NHM shall have an XML representation.	CCSDS CMC requires such a representation for Navigation WG standards	Sections 5 and 6
NHM-P11	The NHM shall have the ability to dynamically respond to diverse input data.	The large number and constantly varying types of navigation hardware data require a dynamic configuration to prevent constant updating of the standard as hardware changes.	3.3.4, 5.3.16
NHM-P12	The NHM shall be readable by both humans and computers.	Readability by humans allows rapid evaluation of the form and contents of the data while readability by computers allows processing of large volumes of data and output to other functions of the results.	3.1.1, 6.2.3

Table I-2. Desirable Characteristics

ID	Requirement	Rationale	Trace
NHM-D01	An ICD should be agreed upon between participants in NHM exchanges.	Because hardware data is a diverse and continually changing set, naming conventions, units, and specification of hardware types and characteristics are too diverse and changeable to be specified in a standard. Use of an ICD allows flexibility within a standard format.	3.1.6, Annex E
NHM-D02	The NHM should be extensible with no disruption to existing users/uses.	Space agencies and operators upgrade systems and processes on schedules that make sense for their organizations. In practice, some organizations will be early adopters but others will opt to wait until performance of a new version of the NHM has been proven in other operations facilities.	3.2.2
NHM-D03	The NHM should be as consistent as reasonable with any related CCSDS Recommended Standards used for spacecraft-to-earth applications.	Ideally, the set of Recommended Standards developed by a given CCSDS Working Group will be consistent.	n/a

ANNEX J.

GRAPHICAL REPRESENTATION OF NHM IN KVN

(INFORMATIVE)

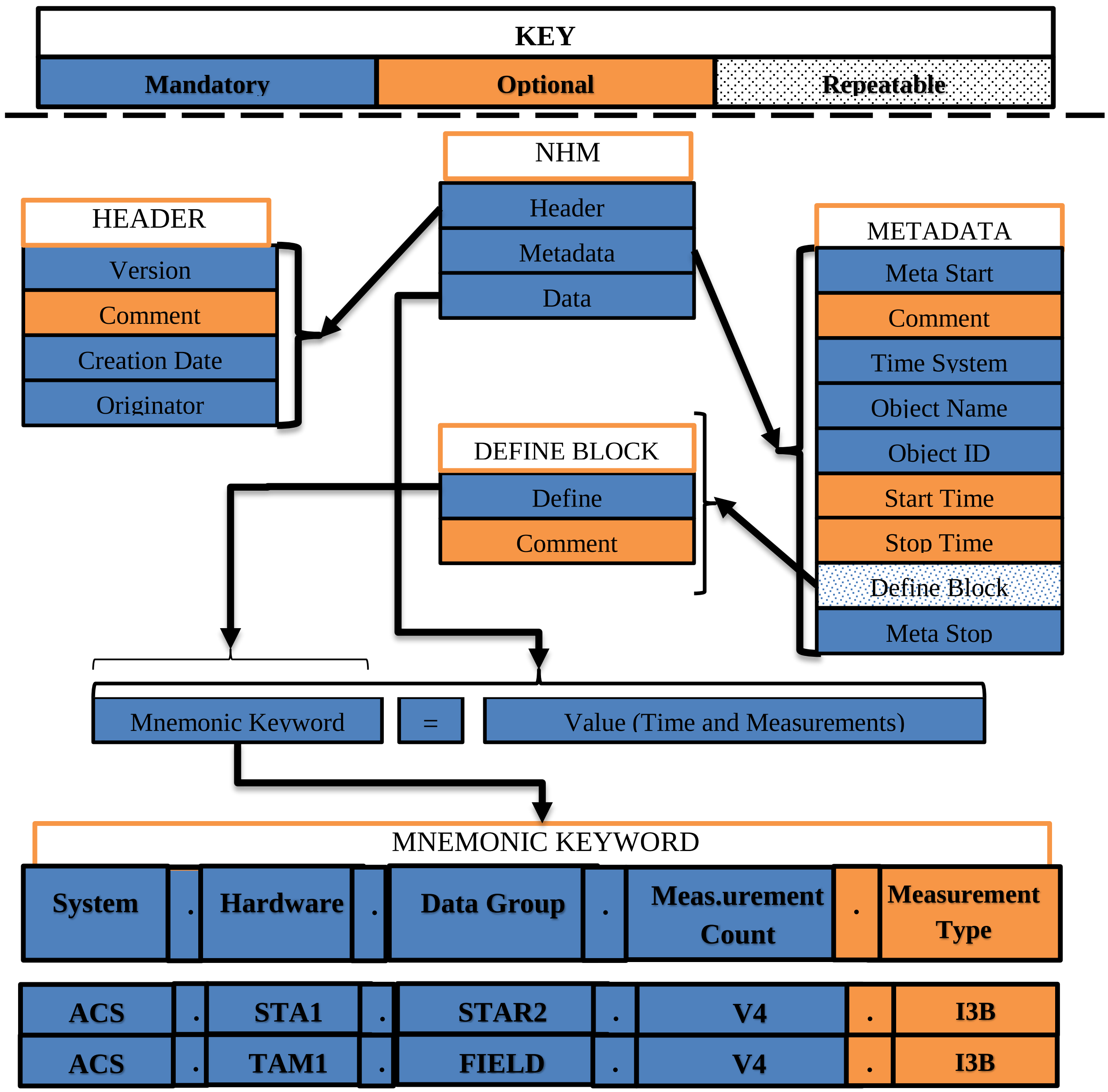

Figure J-1 Graphical Representation of NHM in KVN