CSDS

The Consultative Committee for Space Data Systems

NAVIGATION DATA MESSAGES

CONSISTENCY REPORT

March 2008

Contents

1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to examine the consistency of various aspects of the syntax used in the standards created by the CCSDS Navigation Working Group, collectively called the Navigation Data Messages (AEM, APM, OEM, OMM, OPM, TDM). In particular, there are many portions of these documents where it is reasonable to expect substantial similarity, if not identical content. However, over time, the books have progressed at different rates with different authors. Sometimes RIDs applied to one document based on Agency Review have not been applied to all the documents. It has on occasion been observed that a few of these points of potential commonality have unfortunately diverged. As noted, these observations have been made on a rare basis; to date there has been no comprehensive comparison across the books of these potential points of commonality. This study provides that needed comprehensive comparison.

The document addresses Lines, Keywords, Comments, Values and Units. Each of these components of the Navigation Data Messages is treated in a separate chapter. Each chapter is divided into subsections based on a particular attribute. The text from each document is shown for that particular attribute. If applicable, recommendations and/or comments for correcting divergences are made in the first row, far right column, of each subsection, as well as on individual table rows as necessary.

1.2 GENERAL CONCLUSION

Most attributes are consistent across the various documents, though there are some inconsistencies between the ODM V1 and other documents. This is somewhat to be expected based on the fact that the ODM V1 was the first standard completed by the Working Group. At the time the ODM V1 document was completed, there was a general intention to model the subsequent books (ADM, TDM) after it. However, there have been some divergences in the later books due to the influences of (a) RIDs received during Agency Review, (b) influences caused by the development of the NDM/XML, (c) consolidation of sections for document efficiency, and (d) individual author wording preferences. Most divergences in wording are insignificant and cause no problems. Others are more problematic. Specific recommendations for dealing with these are noted in the subsections. Note that while this study was being conducted, it was possible to correct several areas where new inconsistencies were about to be introduced. The greatest areas of divergence across the Navigation Working Group standards are in the areas of (a) allowed case on text values, and (b) placement of comments. In general, it is recommended that the ODM V1 be treated as an historical document, with no changes introduced; however, the Working Group could possibly consider issuing Technical Corrigenda or Pink Sheets to address inconsistencies between the ODM V1 and the works that came later.

2   LINES

	2.1 LINE LENGTH	RECOMMENDATION / COMMENTS
ADM	Each APM and AEM line must not exceed 254 ASCII characters and spaces (excluding line termination character[s]).	All messages except ODM V1 OPM are in sync. See note below.
ODM V1 / OEM	Each OEM line must not exceed 254 ASCII characters and spaces (excluding line termination character[s]).	
ODM V1 / OPM	Each OPM line must not exceed **78** ASCII characters and spaces (excluding line termination character[s]).	There is a difference here in the ODM V1, highlighted in **red**. In ODM V2 the line length is synchronized with the ADM, TDM. Recommend no change to ODM V1.
ODM V2	Each OEM, OPM or OMM line must not exceed 254 ASCII characters and spaces (excluding line termination character[s]).	
TDM	A TDM line must not exceed 254 ASCII characters and spaces (excluding line termination character[s]).	

	2.2 ASCII CHARACTERS IN LINES	RECOMMENDATION / COMMENTS
ADM	Only printable ASCII characters and blanks shall be used. Control characters (such as TAB, etc.) shall not be used, except as indicated below for the termination of lines.	All messages are basically in sync on this attribute, with some slight, inconsequential wording differences in the TDM. No action necessary.
ODM V1 / OEM	Only printable ASCII characters and blanks shall be used. Control characters (such as TAB, etc.) shall not be used.	
ODM V1 / OPM	Only printable ASCII characters and blanks shall be used. Control characters (such as TAB, etc.) shall not be used.	
ODM V2	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.	
TDM	The TDM shall consist of a set of TDM lines. The TDM line must contain only printable ASCII characters and blanks.	
TDM	ASCII control characters (such as TAB, etc.) must not be used, except as indicated below for the termination of the TDM line.	

	2.3 BLANK LINES	RECOMMENDATION / COMMENTS
ADM	Blank lines may be used at any position within the file.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	Blank lines may be used at any position within the file.	
ODM V1 / OPM	Blank lines may be used at any position within the file.	
ODM V2	Blank lines may be used at any position within the file.	
TDM	Blank lines may be used at any position within the TDM.	

	2.4 FIRST HEADER LINE	RECOMMENDATION / COMMENTS
ADM/AEM	The first header line must be the first non-blank line in the file.	All messages are in sync on this attribute. No action necessary.
ADM/APM	The first header line must be the first non-blank line in the file.	
ODM V1 / OEM	The first header line must be the first non-blank line in the file.	
ODM V1 / OPM	The first header line must be the first non-blank line in the file.	
ODM V2	The first header line must be the first non-blank line in the file.	
TDM	The first Header line must be the first non-blank line in the message.	

	2.5 LINE TERMINATIONS	RECOMMENDATION / COMMENTS
ADM	APM and AEM 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.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	OEM 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.	
ODM V1 / OPM	OPM 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.	
ODM V2	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.	
TDM	TDM 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.	

3 KEYWORDS

	3.1 USE OF KVN	RECOMMENDATION / COMMENTS
ADM	All header, metadata, and data lines, with exceptions as noted in <<section#>>, shall use 'keyword = value' notation, abbreviated as KVN.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	All header and metadata elements shall use 'keyword = value' notation, abbreviated as KVN.	
ODM V1 / OPM	All header, metadata, and data lines shall use 'keyword = value' notation, abbreviated as KVN.	
ODM V2	For the OPM and OMM, all header, metadata, and data lines shall use 'keyword = value' notation, abbreviated as KVN. For the OEM, all header and metadata elements shall use KVN notation.	
TDM	All Header, Metadata Section, and Data Section lines, with exceptions as noted below, shall use 'keyword = value' syntax, abbreviated as KVN.	

	3.2 KVN ASSIGNMENTS PER LINE	RECOMMENDATION / COMMENTS
ADM	Only a single 'keyword = value' assignment shall be made on a line.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	Only a single 'keyword = value' assignment shall be made on a line.	
ODM V1 / OPM	Only a single 'keyword = value' assignment shall be made on a line.	
ODM V2	Only a single 'keyword = value' assignment shall be made on a line.	
TDM	Only a single 'keyword = value' assignment shall be made on a TDM line.	

	3.3 WHITE SPACE WITH RESPECT TO KEYWORD	RECOMMENDATION / COMMENTS
ADM	Any white space immediately preceding or following the keyword shall not be significant.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	Any white space immediately preceding or following the keyword shall not be significant.	
ODM V1 / OPM	Any white space immediately preceding or following the keyword shall not be significant.	
ODM V2	Any white space immediately preceding or following the keyword shall not be significant.	
TDM	Any white space immediately preceding or following the keyword shall not be significant.	

	3.4 WHITE SPACE WITH RESPECT TO "="	RECOMMENDATION / COMMENTS
ADM	Any white space immediately preceding or following the 'equals' sign shall not be significant.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	Any white space immediately preceding or following the 'equals' sign shall not be significant.	
ODM V1 / OPM	Any white space immediately preceding or following the 'equals' sign shall not be significant.	
ODM V2	Any white space immediately preceding or following the 'equals' sign shall not be significant.	
TDM	Any white space immediately preceding or following the equals sign '=' shall not be significant.	

	3.5 WHITE SPACE WITH RESPECT TO END OF LINE	RECOMMENDATION / COMMENTS
ADM	Any white space immediately preceding the end of line shall not be significant.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	Any white space immediately preceding the end of line shall not be significant.	
ODM V1 / OPM	Any white space immediately preceding the end of line shall not be significant.	
ODM V2	Any white space immediately preceding the end of line shall not be significant.	
TDM	Any white space immediately preceding the end of line shall not be significant.	

3.6 KEYWORD CASE		RECOMMENDATION / COMMENTS
ADM	Keywords must be uppercase and must not contain blanks.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	Keywords must be uppercase and must not contain blanks.	
ODM V1 / OPM	Keywords must be uppercase and must not contain blanks.	
ODM V2	Keywords must be uppercase and must not contain blanks.	
TDM	Keywords must be uppercase and must not contain blanks.	

3.7 ORDER OF KEYWORD OCCURRENCE		RECOMMENDATION / COMMENTS
ADM	The order of occurrence of obligatory and optional KVN assignments shall be fixed as shown in tables <<table#>>, <<table#>>, and <<table#>> for the APM, and as shown in tables <<table#>> and <<table#>> for the AEM.	All messages are basically in sync on this attribute. There are some new exceptions for a few keywords in late versions of ADM (related to Euler angles and quaternions), but as a general rule this condition still applies. No action necessary.
ODM V1 / OEM	The order of occurrence of obligatory and optional KVN assignments shall be fixed as shown in <<table#>> and <<table#>>.	
ODM V1 / OPM	The order of occurrence of obligatory and optional KVN assignments shall be fixed as shown in <<table#>>, <<table#>>, and <<table#>>.	
ODM V2	The order of occurrence of obligatory and optional KVN assignments shall be fixed as shown in the tables in Section 3, 4, and 5 that describe the OPM, OMM and OEM keywords.	
TDM	The order of occurrence of the obligatory and optional KVN assignments shall be fixed as shown in table <<table>>.	

	3.8 KVN EXCEPTIONS	RECOMMENDATION / COMMENTS
ADM	The keywords COMMENT, META_START, META_STOP, DATA_START and DATA_STOP are exceptions to the KVN syntax.	The ODM V1 makes no statements regarding exceptions to KVN; ODM V2 corrects this oversight. All other documents make appropriate statements regarding exceptions. No action necessary.
ODM V2	The keywords 'COMMENT, META_START, META_STOP , EPHEMERIS_DATA_START, EPHEMERIS_DATA_STOP, COVARIANCE_DATA_START, and COVARIANCE_DATA_STOP are exceptions to the KVN syntax assignment.	
ODM V2	OEM covariance data lines shall not use KVN format, rather, the OEM data line has a fixed structure containing up to 7 required fields (epoch time plus a row from the 6x6 lower triangular form covariance matrix). See Section <<section#>>.	
ODM V2	OEM ephemeris data lines shall not use KVN format, rather, the OEM ephemeris data line has a fixed structure containing 7 required fields (epoch time, 3 position components, 3 velocity components), and 3 optional acceleration components. See Section <<section#>>.	
TDM	The following distinctions in KVN syntax shall apply for TDM lines: – TDM lines in the Header and Metadata Section shall consist of a keyword, followed by an equals sign '=', followed by a single value assignment. Before and after the equals sign, blank characters (white space) may be added, but shall not be required. – TDM lines in the Data Section shall consist of a keyword, followed by an equals sign '=', followed by a value that consists of two primary elements (essentially an ordered pair): a timetag and the measurement or calculation associated with that timetag (either without the other is unusable for tracking purposes). Before and after the equals sign, blank characters (white space) may be added. The timetag and measurement/calculation in the value must be separated by at least one blank character (white space). The keywords COMMENT, META_START, META_STOP, DATA_START, and DATA_STOP are exceptions to the KVN syntax.	

4 COMMENTS

	4.1 COMMENTS OPTIONAL	**RECOMMENDATION / COMMENTS**
ADM	Comment lines shall be optional. See <<section#>> for details regarding the placement of comment lines in an APM. See <<section#>> for details regarding the placement of comment lines in an AEM.	All messages are in sync with respect to the optional nature of comments. Some books mix the statement that they are optional with details about placement. No action necessary.
ODM V1 / OEM	Comment lines shall be optional and may occur at any position in the file after the first line of the header, except that comment lines must not appear within any block of ephemeris lines.	The influence of our NDM/XML document has placed restrictions on the ODM V1 style of doing comments. These restrictions are accommodated in the ADM, ODM V2 and TDM. No changes to ODM V1 are recommended. Recommend a note in NDM/XML that comments are restricted to certain locations, not as free as ODM V1.
ODM V1 / OPM	Comment lines shall be optional. See Section <<section#>> for details regarding the placement of comment lines.	
ODM V2	For the OPM, OMM, and OEM, comment lines shall be optional.	
TDM	Optional comments may appear in specified locations in the Header, Metadata, and Data Sections (see <<section#>>).	

	4.2 **USES FOR COMMENTS**	**RECOMMENDATION / COMMENTS**
ADM	Comments may be used to provide provenance information or to help describe dynamical events or other pertinent information associated with the data. This additional information is intended to aid in consistency checks and elaboration where needed, but shall not be required for successful processing of a file.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	Comments may be used to provide provenance information or to help describe dynamical events or other pertinent information associated with the data. This additional information is intended to aid in consistency checks and elaboration where needed, but shall not be required for successful processing of a file.	
ODM V1 / OPM	Comments may be used to provide provenance information or to help describe dynamical events or other pertinent information associated with the data. This additional information is intended to aid in consistency checks and elaboration where needed, but shall not be required for successful processing of a file.	
ODM V2	Comments may be used to provide provenance information or to help describe dynamical events or other pertinent information associated with the data. This additional information is intended to aid in consistency checks and elaboration where needed, but shall not be required for successful processing of a file.	
TDM	Comments may be used to provide any pertinent information associated with the data that is not covered via one of the keywords. This additional information is intended to aid in consistency checks and elaboration where needed. Comments shall not be required for successful processing of a TDM; i.e., comment lines shall be optional.	

	4.3 "COMMENT" KEYWORD	RECOMMENDATION / COMMENTS
ADM	All comment lines shall begin with the 'COMMENT' keyword followed by at least one space. This keyword must appear on every comment line, not just the first such line. The remainder of the line shall be the comment value. White space shall be retained (shall be significant) in comment values.	Generally all the messages are in sync in this attribute, but see notes below.
ODM V1 / OEM	All comment lines shall begin with the 'COMMENT' keyword followed by a single space. This keyword must appear on every comment line, not just the first such line. The remainder of the line shall be the comment value. White space shall be retained (shall be significant) in comment values.	ODM V1 says "followed by a single space". Later messages grant more flexibility. No changes to ODM V1 are recommended.
ODM V1 / OPM	All comment lines shall begin with the 'COMMENT' keyword followed by a single space. This keyword must appear on every comment line, not just the first such line. The remainder of the line shall be the comment value. White space shall be retained (shall be significant) in comment values.	ODM V1 says "followed by a single space". Later messages grant more flexibility. No changes to ODM V1 are recommended.
ODM V2	All comment lines shall begin with the 'COMMENT' keyword followed by at least one space. This keyword must appear on every comment line, not just the first such line. The remainder of the line shall be the comment value. White space shall be retained (shall be significant) in comment values.	ODM V2 was corrected to be consistent with ADM and TDM.
TDM	All comment lines shall begin with the 'COMMENT' keyword followed by at least one space (note: may also be preceded by spaces). The 'COMMENT' keyword must appear on every comment line, not just the first comment line. After the keyword, the remainder of the line shall be the comment value. White space shall be retained (is significant) in comment values.	Slightly different wording in the TDM, but requirement is equivalent.

	4.4 PLACEMENT OF COMMENTS	RECOMMENDATION / COMMENTS
AEM	Comments are optional and may appear only after the specification of the keyword CCSDS_AEM_VERS, at the beginning of Metadata sections (only after META_START and before OBJECT_NAME), and immediately following the DATA_START keyword. Comments must not appear between attitude ephemeris data lines, nor after the DATA_STOP keyword.	Except for ODM V1, books are in sync with respect to this attribute. No changes to ODM V1 are recommended.
APM	Comments are optional and may appear only at the beginning of the APM Header and APM Metadata sections, as shown in Tables <<table#>> and <<table#>>. In the APM data section, comments shall only appear at the beginning of a logical block. Comments must not appear between the components of any logical block in the APM data section. The logical blocks in the APM Data section are indicated in Table <<table#>>.	
ODM V1 / OEM	Comments may appear anywhere after the first header line, except that comment lines must not appear between ephemeris data lines.	The influence of our NDM/XML document has placed restrictions on the ODM V1 style of doing comments. No changes to ODM V1 are recommended. Recommend a note in NDM/XML that comment placement is not as free as ODM V1 in an XML

4.4 PLACEMENT OF COMMENTS		RECOMMENDATION / COMMENTS
		instantiation.
ODM V1 / OPM	Comments may appear anywhere within the OPM Header and OPM Metadata sections. In the OPM Data section, comments shall only appear at the beginning or end of a logical block. Comments must not appear between the components of any logical block in the OPM Data section. The logical blocks in the OPM Data section are indicated in <<table#>>.	See note above.
ODM V1 / OPM	Comments may appear anywhere within the OPM Header and OPM Metadata sections. In the OPM Data section, comments shall only appear at the beginning or end of a logical block. Comments must not appear between the components of any logical block in the OPM Data section. The logical blocks in the OPM Data section are indicated in <<table#>>.	See note above.
ODM V2	Comments in the OEM may appear in the OEM Header immediately after the 'CCSDS_OEM_VERS' keyword, at the very beginning of the OEM Metadata section (after the 'META_START' keyword), and at the beginning of the OEM Data section.	
ODM V2	Comments in the OPM may appear in the OPM Header immediately after the 'CCSDS_OPM_VERS' keyword, at the very beginning of the OPM Metadata section, and at the beginning of a logical block in the OPM Data section. Comments must not appear between the components of any logical block in the OPM Data section. The logical blocks in the OPM Data section are indicated in <<table#>>.	
ODM V2	Comments in the OMM may appear in the OMM Header immediately after the 'CCSDS_OMM_VERS' keyword, at the very beginning of the OMM Metadata section, and at the beginning of a logical block in the OMM Data section. Comments must not appear between the components of any logical block in the OMM Data section. The logical blocks in the OMM Data section are indicated in <<table#>>.	
ODM V2	Placement of comments shall be as specified in the tables in Section 3, 4, and 5 that describe the OPM, OMM and OEM keywords. For the OEM, comment lines must not appear within any block of ephemeris lines.	
TDM	Comment lines, if used, shall only occur: – at the beginning of the TDM Header (i.e., between the CCSDS_TDM_VERS keyword and the CREATION_DATE keyword, as shown in table <<table#>>); – at the beginning of the TDM Metadata Section (i.e., between the META_START keyword and the TIME_SYSTEM keyword, as shown in table <<table#>>); – at the beginning of the TDM Data Section (i.e., between the 'DATA_START' keyword and the first Tracking Data Record).	

5   VALUES

	5.1 VALUE FIELDS	RECOMMENDATION / COMMENTS
ADM	A non-empty value field must be specified for each keyword provided.	All messages are basically in sync on this attribute, with exceptions as noted below. No action necessary.
ODM V1 / OEM	A non-null value field must be specified for each obligatory keyword.	"null" used instead of "empty" in ODM V1. This was probably changed due to a RID on ADM or TDM. No change to ODM V1 recommended.
ODM V1 / OPM	A non-null value field must be specified for each keyword provided.	"null" used instead of "empty" in ODM V1. This was probably changed due to a RID on ADM or TDM. No change to ODM V1 recommended.
ODM V2	A non-empty value field must be specified for each obligatory keyword.	ODM V2 was updated to be consistent with ADM and TDM.
TDM	A non-empty value field must be specified for each keyword provided.	

	5.2 UNDERSCORES IN TEXT VALUES	RECOMMENDATION / COMMENTS
ADM	**<<missing text>>**	ADM has no statement to this effect. Could add one, but not absolutely necessary.
ODM V1 / OEM	In value fields that are text, an underscore shall be equivalent to a single blank. Individual blanks shall be retained (shall be significant), but multiple blanks shall be equivalent to a single blank.	
ODM V1 / OPM	In value fields that are text, an underscore shall be equivalent to a single blank. Individual blanks shall be retained (shall be significant), but multiple blanks shall be equivalent to a single blank.	
ODM V2	In value fields that are text, an underscore shall be equivalent to a single blank. Individual blanks shall be retained (shall be significant), but multiple blanks shall be equivalent to a single blank.	
TDM	In value fields that are text, an underscore shall be equivalent to a single blank. Individual blanks between non-blank characters shall be retained (shall be significant) but multiple blanks shall be equivalent to a single blank.	

5.3 TEXT VALUE CASE		RECOMMENDATION / COMMENTS
ADM	Text value fields must be constructed using only all uppercase or all lowercase.	This is an area where considerable divergence is possible. Mostly this causes problems in the XML versions of the messages. The ADM direction is probably the right way to go, but is not feasible for ODM V1. Could add this to the "Pink Sheets" for TDM. Another possibility is to add a section to the NDM/XML explaining that text values must be either all upper case or all lower case in an XML instantiation of one of these messages, and not change the underlying KVN standards.
ODM V1 / OEM	Text value fields may be constructed using mixed case. Case shall not be significant.	No change recommended to ODM V1.
ODM V1 / OPM	Text value fields may be constructed using mixed case. Case shall not be significant.	No change recommended to ODM V1.
ODM V2	Text value fields must be constructed using only all uppercase or all lowercase.	ODM V2 was updated to have the ADM statement.
TDM	Text value fields may be constructed using mixed case; case shall not be significant.	Could add the case change to TDM "Pink Sheets".

5.4 BLANKS IN NUMERIC/TIME VALUES		RECOMMENDATION / COMMENTS
ADM	Blanks shall not appear within numeric values and time values.	All messages are in sync on this attribute. Slight variations in wording are inconsequential. No action necessary.
ODM V1 / OEM	Blanks must not appear within numeric values and time strings.	
ODM V1 / OPM	Blanks must not appear within numeric values and time strings.	
ODM V2	Blanks shall not be permitted within numeric values and time strings.	
TDM	Blanks shall not be permitted within numeric values and time values.	

	5.5 TIME VALUES	**RECOMMENDATION / COMMENTS**
ADM	File creation date/time in one of the following formats: YYYY-MM-DDThh:mm:ss[.d→d] or YYYY-DDDThh:mm:ss[.d→d] where 'YYYY' is the year, 'MM' is the two-digit month, 'DD' is the two-digit day, 'DDD' is the three-digit day of year, 'T' is constant, 'hh:mm:ss[.d→d]' is the UTC time in hours, minutes, seconds, and optional fractional seconds. As many 'd' characters to the right of the period as required may be used to obtain the required precision. All fields require leading zeros.	All messages are basically in sync on this attribute. ADM and ODM V1 have the format in the tables, while ODM V2 and TDM have a separate discussion in the "Values" section of the syntax to which the tables are referred. Slight variations in wording and representation of fractional seconds are relatively inconsequential. Some actions recommended below for ODM V2 and possibly for TDM.
ODM V1	File creation date/time in one of following formats: YYYY-MM-DDThh:mm:ss[.tttttt] or YYYY-DDDThh:mm:ss[.tttttt] where "YYYY" is the year, "MM" is the 2 digit month, "DD" is the 2 digit day, "DDD" is the 3 digit day of year, "T" is constant, "hh:mm:ss[.tttttt]" is the UTC time in hours, minutes, seconds, and optional fractional seconds. All fields require leading zeros.	
ODM V2	In value fields that represent a timetag or epoch, 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, 'DDD' is the three-digit day of year, 'T' is constant, 'hh:mm:ss[.d→d]' is the time in hours, minutes seconds, and optional fractional seconds; 'Z' is an optional time code terminator (the only permitted value is 'Z' for Zulu i.e. UTC). As many 'd' characters to the right of the period as required may be used to obtain the required precision. All fields shall have leading zeros. See reference <<reference#>>, ASCII Time Code A or B.	ODM V2 was updated to be consistent with ADM and TDM.
TDM	In value fields that represent a timetag or epoch, one of the following two formats shall be used: 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, 'DDD' is the three-digit day of year, 'T' is constant, 'hh:mm:ss[.d→d]' is the time in hours, minutes seconds, and optional fractional seconds; 'Z' is an optional time code terminator (the only permitted value is 'Z' for Zulu, i.e., UTC). All fields shall have leading zeros. See reference <<reference#>>, ASCII Time Code A and B.	TDM does not have the statement about fractional seconds, but no action is necessary. Could add this to the "Pink Sheets" list.

5.6 INTEGER VALUES		RECOMMENDATION / COMMENTS
ADM	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., -2^{31} <= x <= 2^{31}-1).	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	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 zeroes may be used. The range of values that may be expressed as an integer is: -2,147,483,648 <= x <= +2,147,483,647.	
ODM V1 / OPM	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 zeroes may be used. The range of values that may be expressed as an integer is: -2,147,483,648 <= x <= +2,147,483,647 .	
ODM V2	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 zeroes 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., -2^{31} <= x <= 2^{31}-1).	
TDM	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., -2^{31} <= x <= 2^{31}-1).	

5.7 NON-INTEGER VALUES		RECOMMENDATION / COMMENTS
ADM	Non-integer numeric values may be expressed in either fixed-point or floating-point notation. Both representations may be used within an APM or an AEM.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	Non-integer numeric values may be expressed in either fixed or floating-point notation. Both representations may be used within an OEM.	
ODM V1 / OPM	Non-integer numeric values may be expressed in either fixed or floating-point notation. Both representations may be used within an OPM.	
ODM V2	Non-integer numeric values may be expressed in either fixed-point or floating-point notation. Both representations may be used within an OPM, OMM, or OEM.	
TDM	Non-integer numeric values may be expressed in either fixed-point or floating-point notation. Both representations may be used within a TDM.	

5.8 FIXED-POINT VALUES		RECOMMENDATION / COMMENTS
ADM	Non-integer numeric values expressed in fixed-point 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 1 digit is required before and after a decimal point. The number of digits shall be 16 or fewer.	ADM, ODM V2, and TDM are in sync on this attribute. There are some inconsistencies in ODM V1 that have been adjusted by RIDs during the ADM/TDM Agency Reviews. No action is recommended.
ODM V1 / OEM	Non-integer numeric values expressed in fixed point 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 zeroes may be used. If the fractional part is zero, the period and following zero(es) may be omitted. There must be a leading zero if $-1.0 < x < 1.0$. The maximum number of digits shall be 18 or less.	There are two inconsistencies here that were corrected by RIDs to the ADM and TDM. The ODM V2 is consistent. Recommend no change to ODM V1.
ODM V1 / OPM	Non-integer numeric values expressed in fixed point 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 zeroes may be used. If the fractional part is zero, the period and following zero(es) may be omitted. There must be a leading zero if $-1.0 < x < 1.0$. The number of digits shall be 18 or less.	There are two inconsistencies here that were corrected by RIDs to the ADM and TDM. The ODM V2 is consistent. Recommend no change to ODM V1.
ODM V2	Non-integer numeric values expressed in fixed-point 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 zeroes may be used. At least 1 digit shall appear before and after a decimal point. The number of digits shall be 16 or less.	
TDM	Non-integer numeric values expressed in fixed-point 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 1 digit shall be used before and after a decimal point. The number of digits shall be 16 or fewer.	

	5.9 **FLOATING-POINT VALUES**	**RECOMMENDATION / COMMENTS**
ADM	Non-integer numeric values expressed in floating-point 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 '+' shall be assumed). – The maximum positive floating-point value is approximately $1.798E+308$, with precision of 16 significant decimal digits. The minimum positive floating-point value is approximately $4.94E-324$, with precision of 16 significant decimal digits.	All messages are in sync on this attribute. No action necessary.
ODM V1 / OEM	Non-integer numeric values expressed in floating point 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: 1) The sign may be "+" or "-". If the sign is omitted, "+" shall be assumed. 2) 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. 3) 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 0 shall be assumed (essentially yielding a fixed point value). 4) The exponent must be an integer, and may have either a "+" or "-" sign (if the sign is omitted, then "+"shall be assumed). 5) 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.	
ODM V1 / OPM	Non-integer numeric values expressed in floating point 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: 1) The sign may be "+" or "-". If the sign is omitted, "+" shall be assumed. 2) 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	

5.9	FLOATING-POINT VALUES	RECOMMENDATION / COMMENTS
	mantissa. 3) 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 0 shall be assumed (essentially yielding a fixed point value). 4) The exponent must be an integer, and may have either a "+" or "-" sign (if the sign is omitted, then "+" shall be assumed). 5) 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.	
ODM V2	Non-integer numeric values expressed in floating point 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: 1) The sign may be "+" or "-". If the sign is omitted, "+" shall be assumed. 2) 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. 3) 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 0 shall be assumed (essentially yielding a fixed point value). 4) The exponent must be an integer, and may have either a "+" or "-" sign (if the sign is omitted, then "+" shall be assumed). 5) 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.	
TDM	Non-integer numeric values expressed in floating-point 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).	

5.9	FLOATING-POINT VALUES	RECOMMENDATION / COMMENTS
	– 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.	

	5.10 **NUMERIC VALUES CONFORMANCE TO OTHER SPECS**	**RECOMMENDATION / COMMENTS**
ADM	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. The specifications for floating-point values conform to the IEEE double precision type (reference <<reference#>>). Floating-point numbers in IEEE extended-single or IEEE extended-double precision may be represented, but do require an ICD between participating agencies due to their implementation-specific attributes (reference <<reference#>>). Note that NaN, +Inf, -Inf, and -0 are not supported values.	All messages are basically in sync on this attribute. No action necessary.
ODM V1 / OEM	These specifications for integer, fixed point and floating point values conform to the XML specifications for the data types "integer", "decimal" and "double" respectively. The specifications for floating point values conform to the IEEE double precision type (references <<reference#>>, <<reference#>>). Floating point numbers in IEEE extended-single or IEEE extended-double precision may be represented, but do require an ICD between participating agencies due to their implementation specific attributes (reference <<reference#>>).	
ODM V1 / OPM	These specifications for integer, fixed point and floating point values conform to the XML specifications for the data types "integer", "decimal" and "double" respectively. The specifications for floating point values conform to the IEEE double precision type (references <<reference#>>, <<reference#>>). Floating point numbers in IEEE extended-single or IEEE extended-double precision may be represented, but do require an ICD between participating agencies due to their implementation specific attributes (reference <<reference#>>).	
ODM V2	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 (reference <<reference#>>). The specifications for floating point values conform to the IEEE double precision type (references <<reference#>>, <<reference#>>). Floating point numbers in IEEE extended-single or IEEE extended-double precision may be represented, but do require an ICD between exchange partners due to their implementation specific attributes (reference <<reference#>>). The special values 'NaN', '-Inf', '+Inf', and '-0' are not supported in the ODM.	
TDM	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 ref <<reference#>>). The specifications for floating-point values conform to the IEEE 754 double precision type (see ref <<reference#>>). 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 TDM.	

6   UNITS

	6.1 DISPLAY OF UNITS	**RECOMMENDATION / COMMENTS**

APM	For clarity, units may be included as ASCII text after a value, but they must exactly match the units specified in table <<table#>> (including case). If units are displayed, then:
	   a) there must be at least one blank character between the value and the units text;
	   b) the units must be enclosed within square brackets (e.g., '[deg]');
	   c) multiplication of units shall be denoted with a single asterisk '*' (e.g., '[N*m]').
	   d) exponents of units shall be denoted with a double asterisk (i.e., '**').
		APM and ODM V2 are in sync on this attribute. TDM does not display units. ODM V1 is out of sync as noted below, but no change to ODM V1 is recommended.

ODM V1 / OPM	For clarity, units may be included as ASCII text after a value, but they must match the units specified in <<table#>>. If units are displayed, then:
	   a) there must be at least one blank character between the value and the units text;
	   b) the units must be enclosed within square brackets (e.g., '[km]');
	   c) exponents of units shall be denoted with a double asterisk (i.e., '**'); and
	   d) units documentation may be constructed using mixed case (case shall not be significant).
		Problems with the display of units as described in the ODM V1 are corrected in ODM V2. Recommend no change to ODM V1. Note there is no need for multiplication of units in the ODM.

ODM V2 / OPM,OMM	For documentation purposes and clarity, units may be included as ASCII text after a value. If units are displayed, they must exactly match the units specified in <<table#>> and <<table#>> (including case). If units are displayed, then:
	   a) there must be at least one blank character between the value and the units text;
	   b) the units must be enclosed within square brackets (e.g., '[km]');
	   c) exponents of units shall be denoted with a double asterisk (i.e., '**', for example, $m/s^2 = m/s**2$).
	Note that some of the items in the applicable tables are dimensionless. The table shows a unit value of "n/a", which in this case means that there is no applicable units designator for these items (e.g., for ECCENTRICITY). The notation "[n/a]" should not appear in an OPM or OMM.	

	6.2 NON-DISPLAYED UNITS	**RECOMMENDATION / COMMENTS**
AEM	In an AEM, units shall be assigned to the keywords as follows: – dimensionless: EPOCH, Q1, Q2, Q3, QC; – 1/s: Q1_DOT, Q2_DOT, Q3_DOT, QC_DOT; – deg: X, Y, Z, SPIN_ALPHA, SPIN_DELTA, SPIN_ANGLE, NUTATION, NUTATION_PHASE; – deg/s: X_RATE, Y_RATE, Z_RATE, SPIN_ANGLE_VEL; – s: NUTATION_PER. Units shall not be displayed; the applicable units are determined by the value set for the ATTITUDE_TYPE keyword.	Each of the messages AEM, OEM, TDM have some non-displayed units. These are handled differently, but appropriately given the character of each book and the situations units are not displayed. Recommend no action.
ODM V1 / OEM	In an OEM, units shall be km and km/s but shall not be displayed.	
ODM V2 / OEM	In an OEM ephemeris data line, units shall be km, km/s, and km/s**2 for position, velocity and acceleration components respectively, but the units shall not be displayed. In an OEM covariance matrix line, units shall be km**2, km**2/s, or km**2/s**2 depending on whether the element is computed from two position components, one position component and one velocity component, or 2 velocity components.	
TDM	Units are not explicitly displayed in the TDM. The units associated with values in the TDM are as specified in table <<table#>>.	

7 ACRONYMS

ADM   Attitude Data Messages

AEM   Attitude Ephemeris Message

APM   Attitude Parameter Message

NDM   Navigation Data Messages

NDM/XML   Navigation Data Messages XML Specification

ODM   Orbit Data Messages

OEM   Orbit Ephemeris Message

OMM   Orbit Mean-Elements Message

OPM   Orbit Parameter Message

TDM   Tracking Data Message

XML   eXtensible Markup Lanaguage