The Consultative Committee for Space Data Systems

Proposed Recommendation for Space Data System Standards

SPACECRAFT MANEUVER MESSAGES

PROPOSED STANDARD

CCSDS 511.0-W-4

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(WHEN THIS PROPOSED RECOMMENDED STANDARD IS FINALIZED, IT WILL CONTAIN THE FOLLOWING STATEMENT OF AUTHORITY:)

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FOREWORD

This document is a Proposed Standard that has been prepared by the Consultative Committee for Space Data Systems (CCSDS). The Spacecraft Maneuver Messages described in this Proposed Standard establish a common framework and provides a common format for the interchange of data describing the spacecraft maneuvers that affect the trajectory and/or attitude of a spacecraft. The standard was developed for specific use in applications that are cross- supported between Agencies of the CCSDS, but it is applicable to the activities of other space operators as well. 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.

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

Through the process of normal evolution, it is expected that expansion, deletion, or modification of this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, which are defined in *Organization and Processes for the Consultative Committee for Space Data Systems* (CCSDS A02.1-Y-4). Current versions of CCSDS documents are maintained at the CCSDS Web site:

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- Swedish Space Corporation (SSC)/Sweden.
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PREFACE

This document is a draft CCSDS Recommended Standard. Its 'White Book' status indicates that its contents are not stable, and several iterations resulting in substantial technical changes are likely to occur before it is considered to be sufficiently mature to be released for review by the CCSDS Agencies.

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

Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

DOCUMENT CONTROL

Document	Title and Issue	Date	Status
CCSDS 511.0-W-1	Spacecraft Maneuver Message, Proposed Standard, Issue 1	April 2012	Initial draft
CCSDS 511.0-W-2	Spacecraft Maneuver Message, Proposed Standard, Issue 2	February 2013	2nd draft
CCSDS 511.0-W-3	Spacecraft Maneuver Message, Proposed Standard, Issue 3	March 2014	3rd draft
CCSDS 511.0-W-4	Spacecraft Maneuver Messages, Proposed Standard, Issue 4	November 2014	4th draft

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Table

1 INTRODUCTION, PURPOSE AND SCOPE

The Spacecraft Maneuver Message (SMM) allows space agencies and operators to exchange information in a standardized format about spacecraft maneuvers that affect the trajectory and/or attitude of a spacecraft.

Spacecraft maneuvers documented via the SMM are intentional changes in trajectory and/or attitude. The SMM covers both planned maneuvers and reconstructed maneuvers. This standard does not include environmental (external) perturbations, outgassing, or perturbations caused by ejecting or releasing mass.

1.1 APPLICABILITY AND RATIONALE

The SMM facilitates interoperability between space agencies and other spacecraft operators; e.g., where navigation functions for a mission of Agency/Operator A are performed by Agency/Operator B. It could be used internally between teams within a single organization as well. Throughout the remainder of this document the term 'spacecraft operator' represents any agency or company which is delivering or receiving an SMM.

This Recommended Standard is applicable only to the message format and content, but not to its transmission. The method of transmitting the message between exchange partners 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 and the technical data content of an SMM are independent. It is recommended that the transmission method be documented in an Interface Control Document (ICD) between the exchange partners.

It is necessary to factor the perturbations caused by spacecraft maneuvers described in this message into spacecraft navigation solutions. Prior to this recommendation there was no formal standard by which such data are conveyed between the navigation team, the propulsion engineers and the spacecraft operators.

For precise spacecraft navigation, it is essential to have knowledge of the forces/torques perturbing the spacecraft orbit/attitude states arising from spacecraft maneuvers. For inter-spacecraft-operator exchanges, it is desirable to exchange information regarding these data in a standardized format. Spacecraft maneuver data are currently presented in numerous formats, though the information regarding the perturbation to the spacecraft state is similar in content, i.e., there are x-, y-, and z-axis components relative to a spacecraft in some reference frame.

The SMM provides to Guidance, Navigation and Control (GN&C), flight operations and science teams information regarding measured or predicted accelerations on the spacecraft, the cumulative delta-V effect of thruster firings over one or more specified intervals of time, the cumulative torque effect on angular momentum, and/or the cumulative spacecraft mass loss due to the use of propellant in those thrusters. Currently maneuver data is exchanged using files that can vary in format from one spacecraft to another, sometimes even within the same spacecraft operator. The SMM offers a standard as an alternative to the various formats currently in use.

1.2 DOCUMENT STRUCTURE

Section 1 (this section) provides introductory matter.

Section 2 provides a brief overview of spacecraft maneuvers and the Spacecraft Maneuver Message (SMM) types: the Maneuver Planning Message (MPM), the Maneuver Design Message (MDM), and the Maneuver Analysis Message (MAM).

Section 3 discusses the structure and content of the SMMs in Key Value Notation (KVN) format. A general section applying to all SMM types is followed by sections describing the MPM, MDM and MAM in more detail.

Section 4 discusses the structure and content of the SMMs in EXtensible Markup Language (XML) format. Examples of each SMM type in XML are included.

Section 5 discusses the KVN and XML syntax rules for the SMMs.

Annex A presents the normative Implementation Conformance Statement Proforma.

Annex B provides a normative list of approved values for selected SMM metadata keywords.

Annex C discusses security considerations for the SMMs, patent issues and SANA requirements.

Annex D provides a list of acronyms and abbreviations used in the Recommendation.

Annex E lists a number of items to be covered in inter-spacecraft-operators ICDs prior to exchanging SMMs on a regular basis.

Annex F provides examples of MPMs, MDMs and MAMs in KVN format.

Annex G provides examples of MPMs, MDMs and MAMs in XML format.

Annex H provides the requirements for the SMMs.

Annex I provides a list of informative references.

1.3 DEFINITION OF TERMS

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

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,

e) the word ‘maneuver’ represents a single maneuver effected by the spacecraft propulsive system, either a trajectory changing or attitude changing,

f) the term ‘maneuver(s)’implies one or multiple maneuvers,

g) the terms ‘orbit maneuver’, ‘delta-velocity’ and ‘delta-V’ implies any trajectory-changing maneuver,

h) the term ‘attitude maneuver’ represents any intentional change to the attitude state, including ‘attitude slews’, ‘momentum unloads’, ‘delta-H’.

1.4 CONVENTIONS

TBD

1.5 REFERENCES

[Only references required for the implementation of the specification are listed in the References subsection. See CCSDS A20.0-Y-4, CCSDS Publications Manual (Yellow Book, Issue 4, April 2014) for additional information on this subsection.]

The following publications contain provisions which, through reference in this text, constitute provisions of this document. At the time of publication, the editions indicated were valid. All publications are subject to revision, and users of this Recommended Standard are encouraged to investigate the possibility of applying the most recent editions of the publications indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS publications.

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

[2] "JPL Solar System Dynamics." Solar System Dynamics Group. <http://ssd.jpl.nasa.gov/>

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

[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] Navigation Data Messages / XML Specification, CCSDS 505.0-B-1.0. Blue Book. Washington, D.C.: CCSDS, December 2010.

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

[7] Paul V. Biron and Ashok Malhotra, eds. XML Schema Part 2: Datatypes. 2nd Edition. W3C Recommendation. N.p.: W3C, October 2004. <http://www.w3.org/TR/2001/REC-xmlschema-2-20010502/>

2 OVERVIEW

2.1 GENERAL

Spacecraft maneuvers induce variations in the nominal trajectory and attitude of a spacecraft. Spacecraft maneuvers represented in the SMM are propulsive, using thrust to change the trajectory (force) and/or attitude (torque) of the spacecraft.

Some perturbations caused by maneuvers are measured by various spacecraft instruments, and the data is downloaded in spacecraft telemetry and formatted into files by spacecraft teams. Some maneuver perturbations are predicted from various models or are estimated by orbit determination processes. To describe the perturbations, it is necessary to define a reference frame, which consists of an identifier name, name of center, and a set of three orthogonal axes. In addition, the identifier of the object to which the perturbations are applied, the perturbing source, an epoch time, and accelerations along each axis (x, y, z) are necessary.

NOTE: mnvrs can be described as magnitude and angle or angles, e.g. magnitude, az & el, or magnitude, phase angle. Should we consider these?

The names of general types of spacecraft hardware associated with propulsive maneuvers are standardized herein, e.g., THRUSTER, TANK, PRESSURE. Other names are mission specific, requiring more background explanation, e.g., TCM_THRUSTER#1. An Interface Control Document (ICD) developed mutually by the exchanging entities is recommended for the purpose of providing mission-specific background information. Appendix F provides recommendations for material to be included in an ICD.

2.2 TYPES OF SPACECRAFT MANEUVER MESSAGES

SMMs are exchanged for different purposes and may require varying degrees of technical information. The SMM has been structured as three separate messages to represent three levels of complexity:

Table 2-1 Types of SMMs

SMM Type	Usage	General Contents	Comments
Maneuver Planning Message (MPM)	Notification of or request for a future maneuver(s)	Maneuver purpose, Start time, approximate duration. Can contain desired dV, dH or slew direction(s) & magnitude(s).	Useful for notifying users of the spacecraft's data that data may be unavailable or noisy during this time period. Assists in scheduling resources such as tracking

			network support
Maneuver Design Message (MDM)	Convey detailed parameters for commanding a spacecraft maneuver	MPM contents plus desired mnvr magnitude(s) and direction(s), expected orbit/attitude changes, propulsion configuration	An ICD between the maneuver designer and the mission operations team defining spacecraft specific data is recommended
Maneuver Analysis Message (MAM)	Convey actual performance of commanded maneuver	MDM plus measured/reported values for maneuver, accuracy of maneuver	Characterize performance of propulsion system, manage fuel

The MPM permits the exchange of general information about maneuvers without provided proprietary or sensitive spacecraft data. It can be used for an initial request for the mission operators to include the maneuver in the operations schedule, as well as a notification to users of the spacecraft data that there is an upcoming maneuver event which may cause loss or degradation of data, or a maneuver has occurred if the SPM is used after the maneuver event. Agencies exchanging SMMs may choose to implement SMMs are exchanged for different purposes and may require varying degrees of technical information. The SMM has been structured as three separate messages to represent three levels of complexity

The SMM structure is designed so that all obligatory data in the MPM is included in the MDM, and all obligatory data in the MDM is included in the MAM, permitting a building block approach. In some cases only an MPM will ever be needed and in others the full reconstructed and calibrated maneuver results are required. Exchanging entities may choose to implement the full MAM and use it for all three levels of maneuver information exchange, maneuver notification, design and post-burn analysis. In some cases, an entity interested in the designed maneuver may have no need for the actual maneuver performance, and could receive a MDM as the final maneuver-related product.

Section 3 will first describe the general structure of the SMM, followed by Metadata and Data sections for each SMM type; examples of all 3 types will be included in Appendices E & F.

OLD TEXT: There are 3 Spacecraft Maneuver Messages described here. The 3 flavors are incremental: Maneuver Planning Message (MPM), Maneuver Design Message (MDM), and Maneuver Analysis Message MAM). The MPM describes the basic objective of the maneuver, the MDM describes in detail how that objective will be achieved, the MAM reports the actual maneuver performance.

Need to provide an attitude profile that accompanies the maneuver. Leave out solar sails, etc. for version 1. Include ion propulsion maneuvers in this background information.

ISS uses "control moment gyros" to effect attitude maneuvers and automatic attitude maintenance.

2.3 EXCHANGE OF MULTIPLE MESSAGES

TBS

3 SPACECRAFT MANEUVER MESSAGE (SMM) CONTENT/STRUCTURE IN KVN

This section discusses the structure and content for the SMM. Examples based on this structure and content for each type of SMM are provided in Annexes E and F

3.1 SMM STRUCTURE

3.1.1 The SMM shall consist of maneuver data for one spacecraft at multiple epochs contained within a specified time range.

3.1.2 The SMM shall consist of digital data represented as plain ASCII text lines.

3.1.3 The SMM shall be represented as a combination of:

a) a single Header (see 3.x)
b) a Body, containing Segment(s) (see 3.x)
c) Segment(s), comprising:
   i. Metadata Section (data about data) (see 3.x); and
   ii. Data Section (maneuver information) (see 3.x).

3.1.4 Optional comments may appear in specified locations in the Header, Metadata, and Data Sections (see 3.x).

3.1.5 There shall be no limit to the number of Segments in a given SMM, beyond practical constraints, as shown in Table 3-1.

3.1.6 Each Data Section consists of a minimum of one Maneuver Data Record. Therefore, the overall structure of the SMM shall be:

- SMM = Header + Body
- Body = Segment [+ Segment + ... + Segment];
- Segment = Metadata Section + Data Section;
- Data Section = Spacecraft Maneuver Record (SMR) [+ SMR + SMR ... + SMR].

3.1.7 If the SMM data is contained in a file, the file naming scheme shall be agreed to on a case-by-case basis between the participating spacecraft operators, typically specified in an ICD.

3.1.8 If the SMM data is contained in a file, the method of exchanging files shall be decided on a case-by-case basis by the participating spacecraft operators and documented in an ICD.

Table 3-1: SMM Structure

Item			**Obligatory?**
Header			Yes
Body	Segment 1	Metadata 1	Yes
		Data 1	
	Segment 2	Metadata 2	No
		Data 2	
	.	.	
	Segment n	Metadata n	No
		Data n	

3.2 SMM HEADER

3.2.1 The SMM Header shall include the basic identifying parameters of the message.

3.2.2 Each line in the SMM Header, with certain exceptions, shall have the following generic 'keyword = value' format (KVN): keyword = value

3.2.3 A description of SMM Header items and values is provided in Table 3-2, which specifies for each item:
- the keyword to be used;
- a short description of the item;
- examples of allowed values; and
- whether the item is obligatory or not obligatory.

3.2.4 Only those keywords shown in Table 3-2 shall be used in an SMM Header.

3.2.5 The first Header line must be the first non-blank line in the message.

3.2.6 The order of occurrence of the Header keywords shall be fixed as shown in Table 3-2.

Table 3-2: SMM Header

Keyword	Description	Examples	Obligatory
CCSDS_SMM_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.	0.5 (for testing) 1.0	**Yes**
COMMENT	Any information deemed useful to the SMM recipient as determined by the SMM producer.	COMMENT This data is important.	**No**
CREATION_DATE	Data creation date/time in UTC, in CCSDS ASCII Time Code A or Time Code B [1].	2013-11-06T11:17:33 2014-204T15:56:23.4 2015-001T00:00:00Z	**Yes**
ORIGINATOR	Creating spacecraft operator	CNES, ESA, NASA/JPL, JAXA, etc.	**Yes**

3.3 SMM METADATA

3.3.1 The SMM shall include at least one Metadata Section that contains descriptive configuration details (metadata) applicable to the associated Data Section

3.3.2 A single SMM Metadata Section shall precede each Data Section.

3.3.3 Each line in the SMM Metadata Section, with certain exceptions, shall have the following generic 'keyword = value' format (KVN): keyword = value.

3.3.4 The first line of an SMM Metadata Section (following the Header) shall be the keyword 'META_START'

3.3.5 The last line of an SMM Metadata Section (prior to the Data Section) shall be the keyword 'META_STOP'.

3.3.6 When there are changes in the values assigned to any of the keywords in the Metadata Section, a new Segment must be started (e.g., change in the type and/or source of perturbation, change in reference frame, etc.).

3.3.7 Table 3-3 specifies for each Metadata item:

- the keyword to be used;
- a short description of the item;
- examples of allowed values; and
- whether the item is obligatory or not obligatory

3.3.8 Only those keywords shown in Table 3-3 shall be used in a SMM Metadata Section.

3.3.9 Obligatory items shall appear in every SMM Metadata Section.

3.3.10 Items that are not obligatory may or may not appear in any given SMM Metadata Section, at the discretion of the data producer, based on the requirements of the data and its intended application.

3.3.11 The order of occurrence of the Metadata keywords shall be fixed TBD as shown in Table 3-3 The "N/E" column indicates whether the data in the "Normative Values / Examples" column is normative (N) or an example (E).

Table 3-3: SMM Metadata

Keyword	Description	Normative Values / Examples	N/E	Obligatory?
META_START	The META_START keyword shall delineate the start of the SMM Metadata Section within the message. It must appear on a line by itself; i.e., it shall have no parameters, time tags or values.	N/A	N/A	Yes
COMMENT	Any information deemed useful to the SMM recipient as determined by the SMM producer	COMMENT This is Important Data	N/A	No
OBJECT_NAME	Spacecraft name for which the maneuver data is provided. There is no CCSDS-based restriction on the value for this keyword, but it is recommended to use names from the SPACEWARN Bulletin [6], which include Object name and international designator of the participant.	EUTELSAT W1 JWST CLEMENTINE	E	Yes
CENTER_NAME	Origin of reference frame, which may be the spacecraft, a natural solar system body (planets, asteroids, comets, and natural satellites), including any planet barycenter or the solar system barycenter, or another spacecraft (in this case the value for 'CENTER_NAME' is subject to the same rules as for 'OBJECT_NAME'). There is no CCSDS-based restriction on the value for this keyword, but for natural bodies it is recommended to use names from the NASA/JPL Solar System Dynamics Group at http://ssd.jpl.nasa.gov [2].	EARTH EARTH BARYCENTER MOON SOLAR SYSTEM BARYCENTER SUN JUPITER BARYCENTER EROS	E	Yes
REF_FRAME	Name of the reference frame in which the maneuver data are given. The full set of allowed values is shown in annex A.	ICRF ITRF-2008 TOD EME2000 RTN	E	Yes
REF_FRAME_EPOCH	Epoch of reference frame, if not intrinsic to the definition of the reference frame. Format is CCSDS Time Code A or Time Code B [1].	1996-12-18T14:28:15.1172 1996-277T07:22:54 2006-001T00:00:00Z	E	No
TIME_SYSTEM	The TIME_SYSTEM keyword shall specify the time system used for time tags in the Metadata and associated Data Section. The full set of allowed values is shown in annex A.	UTC TAI GPS SCLK	E	Yes
START_TIME	The START_TIME keyword shall specify the start time of the total time span covered by the data immediately following this Metadata Section. For data accumulation periods, this is the start time	2013-12-18T14:28:15.1172 2024-277T07:22:54 2016-001T00:00:00Z	E	Yes

	of the accumulation. Format is CCSDS Time Code A or Time Code B [1].			
USEABLE_START_TIME	Optional start time of the USEABLE time span covered by the maneuver data immediately following this metadata block. To allow for proper interpolation near the ends of the data block it may be necessary, depending upon the interpolation method to be used, to utilize this keyword with values within the time span covered by the data records as denoted by the START/STOP_TIME time tags. Format is CCSDS Time Code A or Time Code B [1]. This keyword is an optional item, and thus may not be necessary, depending on the recommended interpolation method.	2013-12-18T14:28:15.1172 2024-277T07:22:54 2016-001T00:00:00Z	E	No
USEABLE_STOP_TIME	Optional stop time of the USEABLE time span covered by the maneuver data immediately following this metadata block. To allow for proper interpolation near the ends of the data block it may be necessary, depending upon the interpolation method to be used, to utilize this keyword with values within the time span covered by the data records as denoted by the START/STOP_TIME time tags. Format is CCSDS Time Code A or Time Code B [1]. This keyword is an optional item, and thus may not be necessary, depending on the recommended interpolation method	2013-12-18T14:28:15.1172 2024-277T07:22:54 2016-001T00:00:00Z	E	No
STOP_TIME	The STOP_TIME keyword shall specify the stop time of the total time span covered by the data immediately following this Metadata Section. For data accumulation periods, this is the stop time of the accumulation. Format is CCSDS Time Code A or Time Code B [1].	2013-12-18T14:28:15.1172 2024-277T07:22:54 2016-001T00:00:00Z	E	No
DURATION	Optional keyword to specify the duration of the maneuver in seconds	3.45 0.12345 1800.37		Yes
INTERPOLATION	Used to specify the recommended interpolation method for data points in the set of data, if applicable.	HERMITE LAGRANGE LINEAR	E	No
INTERPOLATION_DEGREE	Recommended interpolation polynomial degree. Must be an integer value. Must be used if the INTERPOLATION keyword is used.	7 1	E	No
MANEUVER_TYPE	Used to indicate the type of perturbation effect on the spacecraft.	ORBIT, ATTITUDE	N	Yes
PERTURBATION_SOURCE	Source of the forces/torques on the OBJECT, such as those induced by a spacecraft specific mechanism, e.g., a	THRUSTER_XYZ, JET 1	E	Yes

	thruster. The value should be the name of the force or the name of the thruster (e.g., ACS thruster #1, RCS thruster #5, descent thruster #2, TCM thruster #3, etc.). For spacecraft specific forces, such as those associated with thrusters, the details should be specified in an ICD. Individual words in the name should be separated with underscores. A number of examples (not an exhaustive list) are provided at right.			
DATA_TYPE	This keyword determines the format of the Maneuver Data Record and the units associated with the value(s). The value associated with this keyword must be selected from the values at right. Note that the data for thruster activity may be either Delta-V or acceleration, based on spacecraft operator preference.	DELTAV ACCELERATION DELTA_MASS DELTA_ANGULAR_VELOCITY ANGULAR_ACCELERATION DELTA_INERTIA DELTAV/DELTA_MASS ACCELERATION/DELTA_MASS DELTA_ANGULAR_VELOCITY/DELTA_INERTIA ANGULAR_ACCELERATION/DELTA_INERTIA TORQUE	N	Yes
SMM_TYPE	States whether or not the value is a predicted value based on modeling, actual data based on measurements or reconstruction	MPM, MDM,MAM	N	Yes
CONTINUITY	States the continuity of the maneuver	CONTINUOUS, DISCONTINUOUS, PULSED		Yes
META_STOP	The META_STOP keyword shall delineate the end of the SMM Metadata Section within the message. It must appear on a line by itself; i.e., it shall have no parameters, time tags, or values.	N/A	NA	Yes

3.4 SMM DATA

3.4.1 The SMM shall include at least one Data Section that contains the spacecraft maneuver data described by the attributes in the associated Metadata Section.

3.4.2 A single Data Section shall follow each Metadata Section.

3.4.3 The first line of an SMM Data Section (following the Metadata Section) shall be the keyword 'DATA_START'.

3.4.4 The last line of an SMM Data Section shall be the keyword 'DATA_STOP'.

3.4.5 Within the Data Section, several different types of Maneuver Data Records are supported depending on the value of the DATA_TYPE keyword.

3.5 SMM DATA RECORDS

3.5.1 The Data Section of the SMM Segment shall consist of one or more Maneuver Data Records. Each Maneuver Data Record shall have the following generic format: Timetag value(s).

3.5.2 Each Maneuver Data Record, including the time tag, shall be provided on a single line.

3.5.3 At least one space character must be used to separate the items in each Maneuver Data Record

3.5.4 The order in which maneuver data items appear is not obligatory; a suggested order is shown below in column 3 of Table 3-4

3.5.5 Table 3-4 lists the allowable combinations of data items. The choice of one of the formats in table 3-4 shall be specified via the DATA_TYPE keyword in the metadata**.**

Table 3-4 SMM Data Records

Keyword	**Value**	**Maneuver Data Line**
DATA_TYPE Options (note that keywords and values appear only in Metadata)		
MANEUVER_TYPE	ORBIT	N/A

DATA_TYPE	DELTAV	Epoch, X_DOT, Y_DOT Z_DOT, or Epoch, VX, VY, VZ
	ACCELERATION	Epoch, X_DDOT, Y_DDOT Z_DDOT, or Epoch, AX, AY, AZ
	DELTA_MASS	Epoch, DMASS
	DELTAV/DELTA_MASS	Epoch, X_DOT, Y_DOT, Z_DOT, DMASS
	ACCELERATION/DELTA_MASS	Epoch, X_DDOT, Y_DDOT, Z_DDOT, DMASS
MANEUVER_TYPE	ATTITUDE	N/A
DATA_TYPE	DELTA_ANGULAR_VELOCITY	Epoch, X_ANGLE, Y_ANGLE, Z_ANGLE, X_RATE, Y_RATE,Z_RATE
	ANGULAR_ACCELERATION	Epoch, TBD
	DELTA_INERTIA	Epoch, IXX, IXY, IXZ
	TORQUE	Epoch, X_TORQ, Y_TORQ, Z_TORQ
	DELTA_ANGULAR_VELOCITY/DELTA_INERTIA	Epoch, TBD
	ANGULAR_ACCELERATION/DELTA_INERTIA	Epoch, TBD

3.5.6 If the DATA_TYPE is "DELTA-V" (either predicted or measured), then the elements shall be the time tag, X_COMPONENT, Y_COMPONENT, Z_COMPONENT, THRUST_COUNT, THRUST_DURATION. The time tag shall be formatted as described in 4.4.9. The THRUST_COUNT shall be the number of firings during the accumulation period for the thruster. The THRUST_DURATION shall be the accumulated "on" time in seconds during the accumulation period for the thruster. The units for the X, Y and Z components shall be km/s. Units shall not be displayed.

3.5.7 If the DATA_TYPE is "ACCELERATION" (either predicted or measured), then the elements shall be time tag, X_COMPONENT, Y_COMPONENT, Z_COMPONENT. The time tag shall be formatted as described in 4.4.9. The units for the X, Y, and Z components shall be km/s**2. Units shall not be displayed.

3.5.8 If the DATA_TYPE is "DELTA_ANGULAR_VELOCITY" (either predicted or measured), then the elements shall be time tag, X_COMPONENT, Y_COMPONENT, Z_COMPONENT. The time tag shall be formatted as described in 4.4.9. The units for the X, Y, and Z components shall be deg/s. Units shall not be displayed.

3.5.9 If the DATA_TYPE is "DELTA-MASS" (either predicted or measured), then the elements shall be time tag, DELTA_MASS. The time tag shall be formatted as described in 4.4.9. The unit for the delta-mass shall be kg. Units shall not be displayed. A mass flow rate may be calculated by interpolating between time tags.

3.5.10 If the DATA_TYPE is "TORQUE" (either predicted or measured), then the elements shall be time tag, X_COMPONENT, Y_COMPONENT, Z_COMPONENT. The time tag shall be formatted as described in 4.4.9. The unit for the torques shall be N*m. Units shall not be displayed.

3.5.11 And so on

3.6 MANEUVER PLANNING MESSAGE (MPM) IN KVN

3.6.1 MPM METADATA

3.6.1.1 TBD.

3.6.2 MPM DATA

3.6.2.1 TBD

3.7 MANEUVER DESIGN MESSAGE (MDM) IN KVN

3.7.1 MDM METADATA

3.7.2 MDM DATA

3.8 MANEUVER ANALYSIS MESSAGE (MAM) IN KVN

3.8.1 MAM METADATA

3.8.2 MAM DATA

4 SMM CONTENT/STRUCTURE IN XML

TBS

4.1 THE SMM XLM SCHEMA

4.2 SMM XML BASIC STRUCTURE

4.3 CONSTRUCTING A SMM XML INSTANCE

5 SMM SYNTAX (KVN)

5.1 OVERVIEW

This section details the syntax requirements for the Spacecraft Maneuver Message. The common syntax used for both KVN and XML formats will be presented, followed by KVN-and XML-specific syntax, respectively.

5.2 SMM LINES

5.2.1 Each SMM file shall consist of a set of lines.

5.2.2 Each SMM line shall be one of the following:

- Header line,
- Metadata line,
- Data line, or
- Blank line.

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

5.2.4 Only printable ASCII characters and blanks shall be used.

5.2.5 ASCII Control characters (such as TAB, etc.) shall not be used, with the exception of the line termination characters specified below.

5.2.6 Blank lines may be used at any position within the file.

5.2.7 Blank lines shall have no assignable meaning, and may be ignored.

5.2.8 The first header line must be the first non-blank line in the file.

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

5.3 KEYWORD = VALUE NOTATION (KVN)

5.3.1 Only a single 'keyword = value' assignment shall be made on a line.

5.3.2 All SMM header and metadata elements shall use KVN notation. .

5.3.3 Maneuver Data Records shall use KVN format; each line has a fixed structure containing some number of required fields depending upon the data type (see 3.6).

5.3.4 Keywords must be uppercase and must not contain blanks.

5.3.5 Any white space immediately preceding or following the keyword shall not be significant.

5.3.6 Any white space immediately preceding or following the 'equals' sign shall not be significant.

5.3.7 Any white space immediately preceding the end of line shall not be significant

5.3.8 The keywords 'COMMENT', 'META_START', 'META_STOP', 'DATA_START', and 'DATA_STOP' are exceptions to the KVN syntax assignment.

5.4 SMM VALUES

5.4.1 A non-empty value field must be specified for each obligatory keyword.

5.4.2 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., $-2^{31} <= x <= 2^{31}-1$).

5.4.3 Non-integer numeric values may be expressed in either fixed-point or floating-point notation.

5.4.4 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 one digit shall appear before and after a decimal point. The number of digits shall be 16 or fewer.

5.4.5 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:

a) The sign may be '+' or '-'. If the sign is omitted, '+' shall be assumed.
b) 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.

c) 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).

d) The exponent must be an integer, and may have either a ‘+’ or ‘-’ sign (if the sign is omitted, then ‘+’ shall be assumed).

e) 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 (reference [5]). The specifications for floating point values conform to the IEEE double precision type (references [5] and [3]). Floating point numbers in IEEE extended-single or IEEE extended-double precision may be represented, but do require an ICD between exchange partners because of their implementation-specific attributes (reference [3]). The special values ‘NaN’, ‘-Inf’ ‘+Inf’, and ‘-0’ are not supported in the SMM.

5.4.6 Text value fields must be constructed using only all uppercase or all lowercase.

5.4.7 Blanks shall not be permitted within numeric values and time strings.

5.4.8 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 contiguous blanks shall be equivalent to a single blank.

5.4.9 In value fields that represent a time tag 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, up to the maximum allowed for a fixed point number. All fields shall have leading zeros. See reference [1], ASCII Time Code A or B.

5.4.10 There are several types of SMM values that represent a time tag or epoch, as shown in the applicable tables. The time system for the CREATION_DATE shall be UTC; the time system for the START_TIME, STOP_TIME, and the measurement time tag shall be as determined by the TIME_SYSTEM metadata keyword.

5.5 SMM UNITS

5.5.1 The units which apply to the elements in the SMM Maneuver Data Record shall be determined by the physical measures.

5.5.2 In an SMM, units shall be assigned to the keywords as follows: TBS

5.5.3 Units shall not be displayed; the applicable units are determined by the value set for the MANEUVER_TYPE keyword.

5.6 COMMENTS

5.6.1 Comment lines may be used in an SMM to provide any information that the SMM producer may feel will be of use to the SMM consumer.

5.6.2 Comment lines shall be optional.

5.6.3 All comment lines shall begin with the ‘COMMENT’ keyword, followed by at least one space.

5.6.4 The ‘COMMENT’ keyword must appear on every comment line, not just the first such line.

5.6.5 Following the ‘COMMENT’ keyword, the remainder of the line shall be the comment value.

5.6.6 The comment value may be used or ignored by the SMM consumer, at their discretion.

5.6.7 Placement of comments in an SMM shall be as specified in the tables in sections 3.3 and 3.4 that describe the SMM Header and Metadata Section respectively.

5.6.8 Comments may be placed in an SMM Data Section immediately following the DATA_START keyword.

6 SMM SYNTAX (XML)

6.1 OVERVIEW

This section details the syntax requirements for the Spacecraft Maneuver Message in XML format.

6.2 XML VERSION, ROOT ELEMENT TAG, AND SMM/XML HEADER

6.2.1 The XML version, root element tag, and SMM/XML header shall be constructed as described in the Section 4. SMM/XML.

6.3 CREATING AN SMM XML INSTANTIATION

6.3.1 A SMM instantiation shall be delimited with the <smm></smm>root element tags using the standard attributes documented in the SMM/XML.

6.3.2 The final attributes of the <smm>tag shall be 'id' and 'version'.

6.3.3 The 'id' attribute shall be 'id="CCSDS_SMM_VERS"'.

6.3.4 The 'version' attribute for the SMM shall be 'version="1.0"'.

6.3.5 The standard SMM header shall follow the <smm> tag.

6.3.6 The SMM <body>shall consist of one or more <segment>constructs.

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

6.3.8 The keywords in the <metadata>and <data>sections shall be those specified in section 3.

NOTE – The rules for including any of the keyword tags in the XML formatted SMM are the same as those specified for the KVN SMM

6.3.9 XML tags for the SMM keywords specified in Section 3 shall be all uppercase.

ANNEX A

IMPLEMENTATION CONFORMANCE STATEMENT PROFORMA

(NORMATIVE)

[Annexes contain ancillary information. Normative annexes precede informative annexes. Informative references are placed in an informative annex. See CCSDS A20.0-Y-4, *CCSDS Publications Manual* (Yellow Book, Issue 4, April 2014) for discussion of the kinds of material contained in annexes.]

ANNEX B

VALUES FOR TIME SYSTEM AND REF_FRAME KEYWORDS

(NORMATIVE)

The values in this annex represent the set of acceptable values for the TIME_SYSTEM and REF_FRAME keywords in the SMM. For details and description of these time systems, see reference [H3]. If exchange partners wish to use different settings, the settings should be documented in the ICD.

B1 TIME_SYSTEM METADATA KEYWORD

Table B-1: Acceptable Values for SMM Time_System Metadata Keywords

Time System Value	Meaning
GMST	Greenwich Mean Sidereal Time
GPS	Global Positioning System
MET	Mission Elapsed Time (note)
MRT	Mission Relative Time (note)
SCLK	Spacecraft Clock (receiver) (requires rules for interpretation in ICD)
TAI	International Atomic Time
TCB	Barycentric Coordinate Time
TDB	Barycentric Dynamical Time
TCG	Geocentric Coordinate Time
TT	Terrestrial Time
UT1	Universal Time
UTC	Coordinated Universal Time

NOTE – If MET or MRT is chosen as the TIME_SYSTEM, then the epoch of either the start of the mission for MRT, or of the event for MET, should either be given in a comment in the message or provided in an ICD. The time system for the start of the mission or the event should also be provided in the comment or the ICD. If these values are used for the TIME_SYSTEM, then the times given in the file denote a duration from the mission start or event. However, for clarity, an ICD should be used to fully specify the interpretation of the times if these values are to be used. Note that the time format should only utilize three digit days from the MET or MRT epoch, not months and days of the months.

B2 REF_FRAME KEYWORD

NOTE: NEED TO IDENTIFY WHAT GEODETICS MODEL IS USED FOR CENTER OF EARTH IE CENTER OF REFERENCE FRAME, OTHER CENTRAL BODIES SUCH AS MARS

NOTE: NEED TO IDENTIFY FUNDAMENTAL PLANE EPOCH SUCH AS J2000 EPOCH 2000 01 01 11:59:58.123 UTC or SIMILAR

NOTE: NEED TO IDENTIFY WHICH EARTH ORIENTATION PARAMETERS UPDATE USED WITH ITRF

Table B-2: Acceptable Values for the Ref_Frame Keyword

Reference Frame Value	Meaning
EME2000	Earth Mean Equator and Equinox of J2000
GCRF	Geocentric Celestial Reference Frame
GRC	Greenwich Rotating Coordinates
ICRF	International Celestial Reference Frame
ITRF2008	International Terrestrial Reference Frame 2008
ITRF-93	International Terrestrial Reference Frame 1993
ITRF-97	International Terrestrial Reference Frame 1997
MCI	Mars Centered Inertial
RSW	Another name for ‘Radial, Transverse, Normal’
RTN	Radial, Transverse, Normal
TDR	True of Date, Rotating
TOD	True of Date
TNW	A local orbital coordinate frame that has the x-axis along the velocity vector, W along the orbital angular momentum vector, and N completes the right handed system.

ANNEX C

SECURITY, SANA AND PATENT CONSIDERATIONS

(INFORMATIVE)

C1 INTRODUCTION

This annex addresses security, SANA and Patent considerations.

C2 SECURITY CONCERNS WITH RESPECT TO THE CCSDS DOCUMENT

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

C2.1 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.

C2.2 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.

C2.3 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.

C2.4 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.

C2.5 AVAILABILITY OF RESOURCES

TBD

C2.6 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.

C2.7 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.

C2.8 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.

C2.9 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 IT Security functionaries of exchange participants.

C2.10 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.

C2.11 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.

C3 SANA CONSIDERATIONS

C3.1 SMM XML

The SMM XML schema will be registered with the SANA.

C3.2 SMM KEYWORDS AND UNITS

A description of SMM keyword types and units will be registered with SANA.

C4 PATENT CONSIDERATIONS

The recommendations of this document have no patent issues.

ANNEX D

ACRONYMS AND ABBREVIATIONS

(INFORMATIVE)

Table D-1: Acronyms and Abbreviations

Acronym/Abbreviation	Meaning
ASCII	American Standard Code for Information Interchange
CCSDS	Consultative Committee for Space Data Systems
CNES	Centre National d'Études Spatiale
ESA	European Space Agency
ICD	Interface Control Document
ICRF	International Celestial Reference Frame
ID	identifier
IEEE	Institute of Electrical and Electronics Engineers
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
ISO	International Organization for Standardization
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
KVN	Keyword = Value notation

MOIMS	Mission Operations and Information Management Services
N/A	Not Applicable / Not Available
NASA	National Aeronautics and Space Administration
SMM	Spacecraft Maneuver Message
UTC	Universal Time Coordinated
XML	Extensible Markup Language

ANNEX E

RECOMMENDED ITEMS FOR INTERFACE CONTROL DOCUMENTS

(INFORMATIVE)

E1 RECOMMENDED ICD ITEMS

In several places in this document there are references to items which supplement an exchange of maneuver data. These items should be specified in an Interface Control Document (ICD) between participants. The ICD should be jointly produced by both participants in a cross-support involving the transfer of maneuver data. This annex compiles those recommendations into a single section.

NOTE: The following table will be filled in as document matures.

Table E-1: Recommended ICD Items

Item	Section
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

ANNEX F

EXAMPLES OF SMMS IN KVN FORMAT

(INFORMATIVE)

NOTE: This section will be filled in when the standard is more mature.

F1 INTRODUCTION

F2 EXAMPLE(S) OF MPM(S) IN KVN FORMAT

F2.1 MAY BE MULTIPLE EXAMPLES

Figure F-1: Example 1 of MPM (KVN)

Figure F-2: Example 2 of MPM (KVN)

F3 EXAMPLE(S) OF MDM(S) IN KVN FORMAT

Figure F-3 Example 1 of MDM (KVN)

Figure F-4 Example 2 of MDM (KVN)

F4 EXAMPLE(S) OF MAM(S) IN KVN FORMAT

Figure F-5 Example 1 of MAM (KVN)

Figure F-6 Example 2 of MAM (KVN)

ANNEX G

EXAMPLES OF SMMS IN XML FORMAT

(INFORMATIVE)

NOTE: This section will be filled in when the standard is more mature.

G1 INTRODUCTION

G2 EXAMPLE(S) OF MPM(S) IN XML FORMAT

G2.1 MAY BE MULTIPLE EXAMPLES

Figure G-1: Example 1 of MPM (XML)

Figure G-2: Example 2 of MPM (XML)

G3 EXAMPLE(S) OF MDM(S) IN XML FORMAT

Figure G-3 Example 1 of MDM (XML)

Figure G-4 Example 2 of MDM (XML)

G4 EXAMPLE(S) OF MAM(S) IN XML FORMAT

Figure G-5 Example 1 of MAM (XML)

Figure G-6 Example 2 of MAM (XML)

ANNEX H

REQUIREMENTS AND RATIONALES FOR THE SMMS

(INFORMATIVE)

H1 RATIONALE

This annex presents the rationale behind the design of this message.

A specification of requirements agreed to by all parties is essential to focus design and to ensure the product meets the needs of the satellite owner/operators and other authorized parties. There are many ways of organizing requirements, but the categorization of requirements is not as important as the agreement on a sufficiently comprehensive set.

H2 REQUIREMENTS AND DESIRABLE CHARACTERISTICS FOR THE SMMS

In this annex 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, satellite owner/operators, or other independent users.
- **Desirable Characteristics**: These are not requirements, but they are felt to be important or useful features of the Recommended Standard.

H2.1 PRIMARY REQUIREMENTS

Table G-1 lists the Primary Requirements accepted by the SMMs, the rationale for each requirement, and the trace to TBD

Table G-1 PRIMARY REQUIREMENTS ACCEPTED BY THE SMMs

#	Requirement	Rationale	Trace
SMM-P01	The SMM data shall be provided in digital form (computer file).	Facilitates computerized processing of SMMs.	
SMM-P02	The SMM shall be provided in data structures (e.g., files) that are readily ported between, and useable within, ‘all’ computing environments in use by satellite owner/operators and other authorized parties.	The CCSDS objective of promoting interoperability is not met if messages are produced using esoteric or proprietary data structures.	

SMM-P03	The SMM shall provide a mechanism by which messages may be uniquely identified and clearly annotated.	Facilitates discussion between a message recipient and the originator should it become necessary.	
SMM-P04	The SMM shall clearly and unambiguously identify the spacecraft performing the maneuver.	Prevents miscommunication.	
SMM-P05	Only one Spacecraft shall be represented in the SMM.	Prevents errors and confusion.	
SMM-P06	The SMM shall support multiple maneuvers in a single file.	Many spacecraft perform multi-maneuver sequences, such as a Hohmann transfer or attitude rotations about single axes in sequence; this will allow a single SMM to represent a maneuver sequence as well as a single maneuver.	
SMM-P07	The SMM shall support translational (trajectory - changing) spacecraft maneuvers.	Translational maneuvers are a very common type of maneuver.	
SMM-P08	The SMM shall support rotational (attitude-changing or momentum unload) spacecraft maneuvers.	Rotational maneuvers are a very common type of maneuver.	
SMM-P09	Each maneuver shall be a single segment in the SMM file.	Provides clarity.	
SMM-P10	The SMM shall contain a unique identifier for each maneuver.	Provides clarity and prevent confusion.	
SMM-P11	The SMM shall be usable for both conveying pre-maneuver planning information and for conveying post-maneuver evaluation. ‘Planning’ in this context includes any pre-maneuver data, including predicted, requested and maneuver profile data. ‘Evaluation’ in this context	Facilitates interoperability and exchange of information if same format can be used for planning and post-maneuver evaluation.	

	includes any post-maneuver data, including reconstructed and calibrated-maneuver information.		
SMM-P12	The SMM shall identify each maneuver segment as trajectory-changing (translational) or attitude-changing (rotational).		
SMM-P14	For each trajectory-changing maneuver segment, the SMM shall provide the trajectory state (e.g. position and velocity) at the maneuver start epoch.	Integral information about the maneuver.	
SMM-P15	For each attitude-changing maneuver segment, the SMM shall provide the attitude state (e.g. quaternions) at the maneuver start epoch.	Integral information about the maneuver.	
SMM-P16	For each maneuver segment, the SMM shall provide the maneuver end conditions with an associated time. The end conditions may be conveyed as a trajectory or attitude state, or as delta-values to the start state. The end time may be conveyed as an epoch or as a maneuver duration. For instantaneous impulsive maneuvers, the maneuver end epoch will be identical to the maneuver start epoch, and the duration will be zero.	Integral information about the maneuver.	
SMM-P17	The SMM shall provide a text description of the intent/goal of the maneuver, e.g. change inclination, raise/lower apsis, rotate line of apsides, orbit insertion, slew to sun pointing, unload momentum, slew to nadir pointing.	Conveys purpose of maneuver.	
SMM-P188	The SMM shall provide trajectory state information in a reference frame that is	Clearly understanding the frame of reference in which measurements are provided is	

	clearly identified and unambiguous.	fundamental to the analysis of most, if not all, physical processes. Cited as required in ISO 16158 (reference [D2]).	
SMM-P19	The SMM shall provide attitude state information in a reference frame that is clearly identified and unambiguous.	Clearly understanding the frame of reference in which measurements are provided is fundamental to the analysis of most, if not all, physical processes. Cited as required in ISO 16158 (reference [D2]).	
SMM-P20	The SMM shall provide for clear specification of units of measure.	Without clear specification of units of measure, mistakes can be made that involve the unit system in effect (e.g., Metric or Imperial) and/or orders of magnitude (e.g., meters or kilometers).	
SMM-P21	The SMM shall provide for a single trajectory maneuver, a single attitude maneuver, or any combination of multiple maneuvers of either type.	Flexibility and facilitates standards, interoperability.	
SMM-P22	The SMM shall allow the possibility to exchange information regarding spacecraft maneuvers orbiting an arbitrary body or point in space.	While Earth is the most common object about which spacecraft maneuver, there are many other orbit centers (e.g., the Moon, Mars, Earth/Sun L1, Earth/Moon L2.	
SMM--P23	The SMM shall provide data and/or metadata that allows the recipient to create maneuver loads for the spacecraft, to evaluate the planned maneuver's impact on spacecraft subsystems, to evaluate the effect of the maneuver after execution.	Facilitates interoperability.	
SMM---P24	The SMM must not require of the receiving exchange partner the separate application of, or modeling of, spacecraft dynamics or	Some operators may not be able to perform the required computations.	

	gravitational force models, or integration or propagation.		
SMM---P25	The source of the pre---maneuver definitive state shall be included, e.g. orbit determination state 1234, attitude determination state 2013---02---24---1300.	Informs the recipient how far in the past the pre---maneuver state is, giving a partial indication of how accurate the maneuver start state is known.	

H2.2 DESIRABLE CHARACTERISITICS

Table G-2 lists the Desirable Characteristics which are recommended for the SMMs, along with the rationale for each characteristic, and the trace to TBD

Table G-2 DESIRABLE CHARACTERISTICS FOR THE SMMs

#	Desired Characteristic	Rationale	Trace
SMM-D01	The SMM 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 SMM has been proven in other operations facilities.	
SMM-D02	The SMM should be as consistent as reasonable with any related CCSDS Recommended Standards used for earth---to---spacecraft or spacecraft---to---spacecraft applications.	Ideally, the set of Recommended Standards developed by a given CCSDS Working Group will be consistent.	n/a
SMM-D03	SMM originators should maintain consistency with respect to the optional keywords provided in their implementations; i.e., the composition of the SMMs provided should not change on a frequent basis.	Implementations that change on a frequent basis do not promote stable operations or interoperability.	
SMM-D04	The SMM should provide for optional parameters which allow the recipient to create spacecraft maneuver command loads.	Not every recipient of the SMM will generate command loads but the SMM should not preclude the ability to provide for this use.	
SMM-D05	The SMM should provide optional parameters indicating actuators used for the maneuver, such as thrusters and reaction wheels.		
SMM-	The SMM should be provided using file name	The CCSDS objective of promoting	

D06	syntax and length that do not violate computer constraints for those computing environments in use by satellite owner/operators and other authorized parties.	interoperability is not met if messages are provided using nonstandard file---name syntax or length.	
SMM-D07	The SMM should provide initial state and end state information regarding the spacecraft hardware used to effect the maneuver. This includes thruster ID, magnitude of thrust, duty cycle, propulsion tank pressure, temperature and fuel mass, mass flow rate, reaction wheel ID, reaction wheel speed.	Similar to start trajectory and start attitude states, provides the assumed or actual state of the subsystem at maneuver start.	
SMM-D08	The SMM should provide end state information regarding the spacecraft hardware used to effect the maneuver. Includes propellant tank pressure, temperature, fuel mass, thruster duty cycle, reaction wheel speed, etc.	Similar to maneuver end conditions, provides the assumed or actual state of the subsystem at maneuver end.	
SMM-D09	The SMM should allow the option to provide interim data during finite maneuvers, such as position/velocity and attitude quaternions.	For long maneuvers, this information is needed in order to compute and maintain station contacts.	
SMM-D10	The SMM should allow the option to provide interim maneuver hardware data during finite maneuvers, such propulsion system pressure and temperature, fuel used, reaction wheel speeds.	For long maneuvers, this information can be used to evaluate the interim spacecraft hardware state, and monitor the maneuver's effectiveness in real-time.	
SMM-D11	The SMM should not be used to convey spacecraft information that does not change, such as thruster location, reaction wheel location, fixed thruster cant angle, fixed thrust arc for spinning spacecraft, etc. If the thruster is steerable, the pointing information may be included in the SMM.	These data should be conveyed in an ICD between the parties.	

NOTE: SMM-D11 may need some revision based on the PRM experience (non-changing information may need to be in the SMM).

ANNEX I

INFORMATIVE REFERENCES

(INFORMATIVE)

NOTE: Normative references are shown in 1.6.

[H1] Richon, Karen V., "CCSDS Concept Paper: Spacecraft Maneuver Message", September, 2010.

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[H3] *Navigation Data—Definitions and Conventions*. Report Concerning Space Data System Standards, CCSDS 500.0-G-2. Green Book. Issue 2. Washington, D.C.: CCSDS, November 2005.

[H4] Bate, R.R., Mueller, D.D., White, J.E., Fundamentals of Astrodynamics, Dover Publications, New York, 1971.

[H5] Chobotov, V.A. (ed.), Orbital Mechanics, 3rd Edition, AIAA, Washington, DC, 2002.

[H6] Tapley, Byron D.; Schutz, Bob E.; Born, George H.; Statistical Orbit Determination, Elsevier Academic Press, 2004.

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[H8] Wertz, James R.; Spacecraft Attitude Determination and Control, Volume 73, Kubler Academic Publishers, 2002.