The Consultative Committee for Space Data Systems

Proposed Recommendation for
Space Data System Standards

CONJUNCTION DATA MESSAGE

PROPOSED STANDARD

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

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FOREWORD

This document is a Proposed Standard for Conjunction Data Messages (CDMs) and has been prepared by the Consultative Committee for Space Data Systems (CCSDS). The CDM described in this Proposed Standard is the baseline concept for conjunction information interchange applications between interested parties.

This Proposed Standard establishes a common framework and provides a common basis for the format of conjunction information exchange between originators of conjunction assessment data and satellite owner/operators. 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 can implement only a subset of the optional features allowed by the Proposed Standard and can incorporate features not addressed by this Proposed Standard.

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- United States Geological Survey (USGS)/USA.

PREFACE

This document is a CCSDS Proposed Standard. Its 'White Book' status indicates that the CCSDS believes the document is not technically mature. As such, its technical contents are not stable, and several iterations of it will occur in response to comments received during the standards development process.

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

DOCUMENT CONTROL

Document	Title and Issue	Date	Status
CCSDS 508.0-W-1	Conjunction Data Message (CDM), Proposed Standard, Issue 1	January 2011	Original issue, superseded
CCSDS 508.0-W-2	Conjunction Data Message (CDM), Proposed Standard, Issue 2	February 2011	Issue 2, superseded
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CCSDS 508.0-W-5	Conjunction Data Message (CDM), Proposed Standard, Issue 5	Aug 2011	Issue 5, superseded
CCSDS 508.0-W-6	Conjunction Data Message (CDM), Proposed Standard, Issue 6	Oct 2011	Issue 6, superseded
CCSDS 508.0-W-7	Conjunction Data Message (CDM), Proposed Standard, Issue 7	Nov 2011	Issue 7, superseded
CCSDS 508.0-W-8	Conjunction Data Message (CDM), Proposed Standard, Issue 8	Dec 2011	Current issue

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

1.1.1 This Conjunction Data Message (CDM) Proposed Standard specifies a standard message format for use in exchanging spacecraft conjunction information between data originators of conjunction assessment (CA), satellite owner/operators and other authorized parties. Such exchanges are used to inform satellite operator(s) of conjunctions between objects in space to enable consistent warning by different organizations employing diverse CA techniques.

1.1.2 This Proposed Standard will:

a) facilitate interoperability and enable consistent warning and mitigation between data originators that supply CA and the satellite operators that use it

b) enable the reuse of software modules that read/write/analyze the CA data

c) facilitate automation for the CA processes

d) provide critical information to enable timely CA decisions.

This Proposed Standard has been developed via consensus of the Navigation Working Group of the CCSDS Mission Operations and Information Management Services (MOIMS) area.

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

1.2 APPLICABILITY

1.2.1 This Proposed Standard is applicable to all satellite operations in environments in which close approaches and collisions among satellites is a concern. It contains the specification for a Conjunction Data Message designed for applications involving conjunction information interchange between data originators of CA and recipients. Conjunction information includes data types such as miss distance, probability of collision, time of closest approach (TCA) and closest approach relative position and velocity. Further information describing the conjunction information contained in this message can be found in Section 3.0 and Annex C.

1.2.2 This message is suited for exchanges that involve manual or automated interaction. The attributes of a CDM make it suitable for use in machine-to-machine interfaces due to the large amount of data typically present. The CDM is intended to be a one way message from the originator to a recipient. The CDM is self contained. However, additional information could be specified in an Interface Control Document (ICD) written jointly by the service originator and recipients.

1.2.3 Users of this Proposed Standard can implement only a subset of the optional features allowed by the Proposed Standard and can incorporate features not addressed by this Proposed Standard. It is desirable that this be documented in an ICD. It is desirable that CDM originators maintain consistency with respect to the optional keywords provided in their implementations, i.e., it is desirable that the composition of the CDMs provided not change on a frequent basis.

1.2.4 This Proposed Standard is applicable only to the message format and content, but not to its transmission nor to the algorithms used to produce the data within. The method of transmitting the message between exchange partners is beyond the scope of this document and could be specified in an ICD.

1.2.5 The methods used to predict conjunctions and calculate the probability of collision are outside the scope of this document. Also, the definition of the conjunction assessment accuracy underlying a particular CDM is outside of the scope of this Proposed Standard.

1.3 DOCUMENT STRUCTURE

Section 2 provides a brief overview of the CCSDS proposed CDM.

Section 3 provides details about the structure and content of the CDM in 'keyword = value notation' (KVN).

Section 4 provides details about the structure and content of the CDM in Extensible Markup Language (XML).

Section 5 addresses the CDM data in general.

Section 6 discusses the syntax considerations of the CDM.

Annex A is a list of abbreviations and acronyms applicable to the CDM.

Annex B provides rationale and requirements for the conjunction data message standard.

Annex C provides a description of the conjunction assessment information contained in the CDM.

Annex D provides informative references.

Annex E provides information on security, the Space Assigned Numbers Authority (SANA) and patent related information.

1.4 DEFINITIONS

1.4.1 UNIT NOTATIONS

The following conventions for unit notations apply throughout this Proposed Standard. Insofar as possible, an effort has been made to use units that are part of the International System of Units (SI Units); units are either SI base units, SI derived units, or units outside the SI that are accepted for use with the SI (see reference [1]). There is one specific case, that of the notation for degrees of plane angle, where the notation that is more widely used in the navigation community is specified ('deg' instead of '°'), but every effort has been made to minimize these departures from the SI.

deg: degrees of plane angle
km: kilometers
m: meters
m/s: meters per second
m**2/s: square meters per second
m**2/s**2: square meters per second squared
d: days, 86400 SI seconds
h: hours, 3600 SI seconds
s: SI seconds
kg: kilograms
W/kg: watt per kilogram

1.4.2 NOMENCLATURE

The CDM contains information about a conjunction between two space objects (hereafter referred to as 'Object1' and 'Object2').

The following nomenclature applies throughout this Proposed Standard:

a) the words 'shall' and 'must' imply a binding and verifiable specification;
b) the word 'should' implies an optional, but desirable, specification;
c) the word 'may' implies an optional specification;
d) the words 'is', 'are', and 'will' imply statements of fact.

1.4.3 CONVENTIONS

The following conventions for syntax apply throughout this Proposed Standard:

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

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

ASCII. A text character set. In this document, ASCII is used generically to refer to the character set defined in reference [2].

1.5 REFERENCES

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

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

[2] *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.

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

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

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

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

2 OVERVIEW

2.1 GENERAL

This section provides a high-level overview of the CCSDS proposed CDM, a message format designed to facilitate standardized exchange of conjunction information between data originators of CA and satellite owner/operators.

2.2 CDM BASIC CONTENT

2.2.1 The proposed CDM is ASCII format encoded either in plain text or XML (see references [2], [3] and [4]). This CDM document describes a 'keyword = value notation' (KVN) formatted message as well as an Extensible Markup Language (XML) formatted message (it is desirable that the ICD specify which of these formats will be exchanged).

2.2.2 The CDM contains information about a single conjunction between Object1 and Object2. It contains the time of the closest approach between Object1 and Object2 and the position, velocity and covariance of Object1 and Object2 at the time of closest approach. It also contains information about how the position, velocity and covariance were determined as well as the relative positions and velocities of Object1 and Object2 at the time of closest approach. This information is used by satellite owner/operators to evaluate the risk of a conjunction and plan maneuvers if deemed warranted by that agency/organization.

2.2.3 Where possible the CDM is consistent with other CCSDS Navigation Data Messages (NDMs). Similar tables have been used to describe header, metadata and data information. Common keywords have been used in order to minimize duplication and confusion (e.g. CREATION_DATE, ORIGINATOR, OBJECT_NAME, OBJECT_ID, etc).

3 CDM CONTENT/STRUCTURE IN KVN

3.1 GENERAL

3.1.1 The CDM in KVN shall consist of digital data represented as ASCII text lines. The lines constituting a CDM shall be represented as a combination of the following:

a) a header;

b) relative metadata/data (metadata/data describing relative relationships between Object1 and Object2);

c) metadata (data about how Object1 and Object2 data were created)

d) data (for both Object1 and Object2); and

e) optional comments (explanatory information).

3.1.2 The CDM shall be a plain text file consisting of CA data for a single conjunction event. The CDM file shall be readily ported between, and useable within, 'all' computing environments in use by Member Agencies. It shall be easily readable by both humans and computers.

3.1.3 The CDM file naming scheme shall be agreed to on a case-by-case basis between the participating parties, typically specified in an ICD. The CDM shall be provided using file name syntax and length that do not violate computer constraints established in standard widely used computing environments.

3.1.4 The method of exchanging CDMs shall be decided on a case-by-case basis by the participating parties and should be documented in an ICD.

3.2 CDM HEADER

3.2.1 Table 3-1 specifies for each KVN header item:

a) the keyword to be used;

b) a short description of the item;

c) examples of allowed values; and

d) whether the item is obligatory or optional.

Table 3-1: CDM KVN Header

Keyword	Description	Example of Values	Obligatory
CCSDS_CDM_VERS	Format version in the form of 'x.y', where 'y' is incremented for corrections and minor changes, and 'x' is incremented for major changes.	1.0, 2.0	Yes
COMMENT	(See 6.2.4 for formatting rules)	COMMENT This is a comment	No
CREATION_DATE	Message creation date/time in UTC. (For format specification, see 6.2.2.11.)	2010-03-12T22:31:12.000 2010-071T22:31:12.000	Yes
ORIGINATOR	Creating agency or operator (value should be specified in an ICD).	JSPOC, ESA, CNES, NASA, SDC	Yes
CDM_FOR	Spacecraft name(s) for which the CDM is provided.	SPOT, ENVISAT, IRIDIUM, INTELSAT	No
MESSAGE_ID	ID that uniquely identifies a message from a given originator. The format and content of the message identifier value are at the discretion of the originator.	201113719185	Yes

3.3 CDM RELATIVE METADATA/DATA

3.3.1 Table 3-2 specifies for each KVN relative metadata/data item:

a) the keyword to be used;

b) a short description of the item;

c) the units to be used;

d) whether the item is obligatory or optional.

Table 3-2: CDM KVN Relative Metadata/Data

Keyword	Description	Units	Obligatory
COMMENT	(See 6.2.4 for formatting rules)	n/a	No
TCA	The time of closest approach (TCA); the date and time in UTC of the predicted conjunction (See 6.2.2.11 for formatting rules).	n/a	Yes
MISS_DISTANCE	The miss distance is the norm of the components of the relative position vector. It indicates how	m	Yes

Keyword	Description	Units	Obligatory
	close the two objects are going to be based upon the conjunction assessment screening results.		
RELATIVE_SPEED	The relative speed is the norm of the components of the relative velocity vector. It defines how fast the two objects are moving relative to each other at the time of the predicted encounter.	m/s	No
RELATIVE_POSITION_R	The R component of Object2's position relative to Object1's position in the RTN coordinate frame (see Annex C for definition).	m	No
RELATIVE_POSITION_T	The T component of Object2's position relative to Object1's position in the RTN coordinate frame (see Annex C for definition) .	m	No
RELATIVE_POSITION_N	The N component of Object2's position relative to Object1's position in the RTN coordinate frame (see Annex C for definition).	m	No
RELATIVE_VELOCITY_R	The R component of Object2's velocity relative to Object1's velocity in the RTN coordinate frame (see Annex C for definition).	m/s	No
RELATIVE_VELOCITY_T	The T component of Object2's velocity relative to Object1's velocity in the RTN coordinate frame (see Annex C for definition).	m/s	No
RELATIVE_VELOCITY_N	The N component of Object2's velocity relative to Object1's velocity in the RTN coordinate frame (see Annex C for definition).	m/s	No
START_SCREEN_PERIOD	The start time in UTC of the screening period for the conjunction assessment. (See 6.2.2.11for formatting rules).	n/a	No
STOP_SCREEN_PERIOD	The stop time in UTC of the screening period for the conjunction assessment. (See 6.2.2.11 for formatting rules).	n/a	No
SCREEN_VOLUME_FRAME	Name of the Object1 centered reference frame in which the screening volume data are given (available options are RTN and TVN (see Annex C for definition)).	n/a	No

Keyword	Description	Units	Obligatory
SCREEN_VOLUME_SHAPE	Shape of the screening volume: ELLIPSOID or BOX.	n/a	No
SCREEN_VOLUME_X	The R or T (depending on if RTN or TVN is selected) component size of the screening volume in the SCREEN_VOLUME_FRAME.	m	No
SCREEN_VOLUME_Y	The T or V (depending on if RTN or TVN is selected) component size of the screening volume in the SCREEN_VOLUME_FRAME.	m	No
SCREEN_VOLUME_Z	The N component size of the screening volume in the SCREEN_VOLUME_FRAME.	m	No
ENTRY_TIME	The time in UTC when Object2 enters the screening volume (See 6.2.2.11 for formatting rules).	n/a	No
EXIT_TIME	The time in UTC when Object2 exits the screening volume (See 6.2.2.11 for formatting rules).	n/a	No
COLLISION_PROBABILITY	The collision probability is the probability that Object1 and Object2 will collide.	n/a	No
COLLISION_PROBABILITY_METHOD	The method that was used to calculate the collision probability (available options are FOSTER-1992, CHAN-1997, PATERA-2001, ALFANO-2005 or OTHER (see Annex C for definition)).	n/a	No

3.4 CDM METADATA

3.4.1 Table 3-3 specifies for each KVN metadata item:

a) the keyword to be used;

b) a short description of the item;

c) normative (N) values or examples (E) of allowed values;

d) the distinction of normative values versus examples of allowed values is specified in the "N/E" column in the table; and

e) whether the item is obligatory or optional.

Table 3-3 and Table 3-4 will be used to define both Object1 and Object2 depending on the value of the keyword OBJECT which is specified in Table 3-3.

Table 3-3: CDM KVN Metadata

Keyword	Description	Normative Values/ Examples	N/E	Obligatory
COMMENT	(See 6.2.4 for formatting rules)	COMMENT This is a comment	E	No
OBJECT	This specifies whether the metadata and data applies to Object1 or Object2.	OBJECT1 OBJECT2	N	Yes
OBJECT_NUMBER	This is the satellite catalog number for the object.	12345	E	Yes
SAT_CATALOG	This is the satellite catalog used for the object.	SATCAT	E	Yes
OBJECT_NAME	Spacecraft name for the object.	SPOT, ENVISAT, IRIDIUM, INTELSAT	E	Yes
OBJECT_ID	This is the full international designator for the object. Values have the format YYYY-NNNP{PP}, where: YYYY = Year of launch. NNN = Three digit serial number of launch (with leading zeros). P{PP} = At least one capital letter for the identification of the part brought into space by the launch. In cases where the object has no international designator, the value UNKNOWN should be used.	2002-021A 2002-009A 1997-020A 1998-037A UNKNOWN	E	Yes
OBJECT_TYPE	This is the object type.	PAYLOAD, ROCKET BODY, DEBRIS, UNKNOWN, OTHER	N	No
OPERATOR_CONTACT_POSITION	Contact position of the operator of the object.	ORBITAL SAFETY ANALYST (OSA), NETWORK CONTROLLER	E	No
OPERATOR_ORGANIZATION	Contact organization of the object.	EUMETSAT, ESA, INTELSAT, IRIDIUM	E	No
OPERATOR_PHONE	Phone number of the contact position for the object .	+49615130312	E	No
OPERATOR_EMAIL	Email address of the contact organization of the object.	HANS.WALDVOGEL@EUMETSAT.INT	E	No
EPHEMERIS_NAME	Unique name of the external ephemeris file used for the object or NONE. This is used to indicate whether an	EPHEMERIS SATELLITE A, NONE	E	Yes

Keyword	Description	Normative Values/ Examples	N/E	Obligatory
	external (i.e. owner/operator (O/O) provided) ephemeris file was used to calculate the CA.			
NUMBER_SENSORS	The number of sensors that were used to provide the observations used in the OD of the object.	1,2,3	E	No
TRACKING_DATA_TYPES	Describes the type(s) of tracking data used in the OD of the object.	RADAR, OPTICAL, GPS, DOPPLER	E	No
ADDITIONAL_TRACKING	Has additional sensor tracking been applied to the OD of the object (see Annex C for definition). YES or NO?	YES, NO	N	No
COVARIANCE_METHOD	Describes if the covariance was calculated during the OD that produced the state vector or a default value was used.	CALCULATED, DEFAULT	N	Yes
MANEUVERABLE	The maneuver capacity of the object.	YES, NO, UNKNOWN	N	Yes
MAN_INCLUDED	In the event that an external ephemeris was used to calculate the CA, this indicates that a maneuver was included in the externally provided ephemeris.	YES, NO	N	No
ORBIT_CENTER	Defines the central body about which Object1 and Object2 orbit. If not specified, the center is assumed to be Earth.	EARTH, SUN, MOON, MARS,	E	No
REF_FRAME	Name of the reference frame in which the state vector data are given (value must be selected from the list of values to the right (see reference [D1]) and be consistent between Object1 and Object2).	GCRF EME2000 ITRF	N	Yes
GRAVITY_MODEL	The gravity model used for the orbit determination (OD) of the object (see Annex C under GRAVITY_MODEL for definition).	EGM-96: 36D 36O, WGS-84_GEOID: 24D 24O, JGM-2 : 41D 41O	E	No
ATMOSPHERIC_MODEL	The atmospheric drag model used for the OD of the object.	JACCHIA 70, MSIS, JACCHIA 70 DCA, NONE	E	No
N_BODY_PERTURBATIONS	The N-body gravitational perturbations that were used	MOON, SUN, MARS, JUPITER	E	No

Keyword	Description	Normative Values/ Examples	N/E	Obligatory
	for the OD of the object.			
SOLAR_RAD_ PRESSURE	Are solar radiation pressure perturbations used for the OD of the object?	YES, NO	N	No
EARTH_TIDES	Are solid earth and ocean tides used for the OD of the object?	YES, NO	N	No
INTRACK_THRUST	Is in-track thrust modeling used for the OD of the object?	YES, NO	N	No

3.5 CDM DATA

3.5.1 Table 3-4 provides an overview of four logical blocks used in the CDM Data section (OD Parameters, Additional Parameters, State Vector and Covariance) and specifies for each data item:

a) the keyword to be used;

b) a short description of the item;

c) the units to be used;

d) whether the item is obligatory or optional.

Table 3-4: CDM KVN Data

Keyword	Description	Units	Obligatory
COMMENT	(See 6.2.4 for formatting rules)	n/a	No
OD Parameters			
COMMENT	(See 6.2.4 for formatting rules)	n/a	No
TIME_LASTOB	The time in UTC of the last accepted observation used in the OD of the object . This can be entered as the exact time (See 6.2.2.11 for formatting rules) or an elapsed time, from the message creation time, that includes the time of the last accepted observation used in the OD of the object. The rules for the latter case are as follows (see 6.2.2.12 for formatting rules): For all near earth (NE) objects: - Less than 6 hours from message creation time - 6 to 12 hours from message creation	n/a or h	No

Keyword	Description	Units	Obligatory
	time - Greater than 12 hours from message creation time For all far from earth (FE) objects (see Annex C under TIME_LASTOB for definition of FE): - Less than 24 hours from message creation time - 24 to 48 hours from message creation time - Greater than 48 hours from message creation time		
RECOMMENDED_OD_SPAN	The recommended OD time span calculated for the object (see Annex C for definition).	d	No
ACTUAL_OD_SPAN	Based on the observations available and the RECOMMENDED_OD_SPAN, this is the actual time span used for the OD of the object (see Annex C for definition).	d	No
MAXIMUM_OBS_GAP	The maximum time between observations accepted for the OD of the object (see Annex C for definition).	h	No
OBS_AVAILABLE	The number of observations available for the OD of the object (see Annex C for definition).	n/a	No
OBS_USED	The number of observations accepted for the OD of the object(see Annex C for definition).	n/a	No
TRACKS_AVAILABLE	The number of sensor tracks available for the OD of the object(see Annex C for definition) .	n/a	No
TRACKS_USED	The number of sensor tracks accepted for the OD of the object (see Annex C for definition).	n/a	No
WEIGHTED_RMS	The weighted RMS of the residuals from a batch least squares OD (see Annex C for definition).	n/a	No
TIME_NEXT_UPDATE	The expected elapsed time from the current OD update, that was used to create the current CDM, to the next OD update.	h	No
Additional Parameters			
COMMENT	(See 6.2.4 for formatting rules)	n/a	No
AREA	The area of the object (see Annex C for definition).	m**2	No
MASS	The mass of the object.	kg	No
CD_ AREA_OVER_MASS	The object's C_D•A/m used to propagate the state vector and covariance to TCA (see Annex C for definition).	m**2/kg	No
CR_ AREA_OVER_MASS	The object's C_r •A/m used to	m**2/kg	No

Keyword	Description	Units	Obligatory
	propagate the state vector and covariance to TCA (see Annex C for definition).		
THRUST_ACCELERATION	The object's acceleration due to in-track thrust used to propagate the state vector and covariance to TCA (see Annex C for definition).	m/s**2	No
SEDR	SEDR is representative of the amount of energy being removed from the object's orbit by atmospheric drag. This value is an average calculated during the OD(see Annex C for definition) .	W/kg	No
State Vector			
COMMENT	(See 6.2.4 for formatting rules).	n/a	No
X	Object Position Vector X component.	km	Yes
Y	Object Position Vector Y component.	km	Yes
Z	Object Position Vector Z component.	km	Yes
X_DOT	Object Velocity Vector X component.	km/s	Yes
Y_DOT	Object Velocity Vector Y component.	km/s	Yes
Z_DOT	Object Velocity Vector Z component.	km/s	Yes
Covariance Matrix in the RTN Coordinate Frame (see Annex C for definition) (Covariance Matrix 9x9 Lower Triangular Form. All parameters of the 6x6 matrix must be given.)			
COMMENT	(See 6.2.4 for formatting rules)	n/a	No
CR_R	Object Covariance matrix [1,1]	m**2	Yes
CT_R	Object Covariance matrix [2,1]	m**2	Yes
CT_T	Object Covariance matrix [2,2]	m**2	Yes
CN_R	Object Covariance matrix [3,1]	m**2	Yes
CN_T	Object Covariance matrix [3,2]	m**2	Yes
CN_N	Object Covariance matrix [3,3]	m**2	Yes
CRDOT_R	Object Covariance matrix [4,1]	m**2/s	Yes
CRDOT_T	Object Covariance matrix [4,2]	m**2/s	Yes
CRDOT_N	Object Covariance matrix [4,3]	m**2/s	Yes
CRDOT_RDOT	Object Covariance matrix [4,4]	m**2/s**2	Yes
CTDOT_R	Object Covariance matrix [5,1]	m**2/s	Yes
CTDOT_T	Object Covariance matrix [5,2]	m**2/s	Yes
CTDOT_N	Object Covariance matrix [5,3]	m**2/s	Yes
CTDOT_RDOT	Object Covariance matrix [5,4]	m**2/s**2	Yes
CTDOT_TDOT	Object Covariance matrix [5,5]	m**2/s**2	Yes
CNDOT_R	Object Covariance matrix [6,1]	m**2/s	Yes
CNDOT_T	Object Covariance matrix [6,2]	m**2/s	Yes
CNDOT_N	Object Covariance matrix [6,3]	m**2/s	Yes
CNDOT_RDOT	Object Covariance matrix [6,4]	m**2/s**2	Yes
CNDOT_TDOT	Object Covariance matrix [6,5]	m**2/s**2	Yes
CNDOT_NDOT	Object Covariance matrix [6,6]	m**2/s**2	Yes
CDRG_R	Object Covariance matrix [7,1]	m**3/kg	No
CDRG_T	Object Covariance matrix [7,2]	m**3/kg	No
CDRG_N	Object Covariance matrix [7,3]	m**3/kg	No
CDRG_RDOT	Object Covariance matrix [7,4]	m**3/kg*s	No
CDRG_TDOT	Object Covariance matrix [7,5]	m**3/kg*s	No
CDRG_NDOT	Object Covariance matrix [7,6]	m**3/kg*s	No
CDRG_DRG	Object Covariance matrix [7,7]	m**4/kg**2	No

Keyword	Description	Units	Obligatory
CSRP_R	Object Covariance matrix [8,1]	m**3/kg	No
CSRP_T	Object Covariance matrix [8,2]	m**3/kg	No
CSRP_N	Object Covariance matrix [8,3]	m**3/kg	No
CSRP_RDOT	Object Covariance matrix [8,4]	m**3/kg*s	No
CSRP_TDOT	Object Covariance matrix [8,5]	m**3/kg*s	No
CSRP_NDOT	Object Covariance matrix [8,6]	m**3/kg*s	No
CSRP_DRG	Object Covariance matrix [8,7]	m**4/kg**2	No
CSRP_SRP	Object Covariance matrix [8,8]	m**4/kg**2	No
CTHR_R	Object Covariance matrix [9,1]	m**2/s**2	No
CTHR_T	Object Covariance matrix [9,2]	m**2/s**2	No
CTHR_N	Object Covariance matrix [9,3]	m**2/s**2	No
CTHR_RDOT	Object Covariance matrix [9,4]	m**2/s**3	No
CTHR_TDOT	Object Covariance matrix [9,5]	m**2/s**3	No
CTHR_NDOT	Object Covariance matrix [9,6]	m**2/s**3	No
CTHR_DRG	Object Covariance matrix [9,7]	m**3/kg*s**2	No
CTHR_SRP	Object Covariance matrix [9,8]	m**3/kg*s**2	No
CTHR_THR	Object Covariance matrix [9,9]	m**2/s**4	No

3.6 CDM/KVN EXAMPLES

Figure 3-1 and figure 3-2 show examples of a CDM message in KVN. Figure 3-1 includes only obligatory keywords and figure 3-2 includes optional keywords as well as obligatory.

```
CCSDS_CDM_VERS          = 1.0
CREATION_DATE           = 2010-03-12T22:31:12.000
ORIGINATOR              = JSPOC
MESSAGE_ID              = 201113719185
TCA                     = 2010-03-13T22:37:52.618
MISS_DISTANCE           = 715                       [m]
OBJECT                  = OBJECT1
OBJECT_NUMBER           = 12345
SAT_CATALOG             = SATCAT
OBJECT_NAME             = SATELLITE A
OBJECT_ID               = 1997-030E
EPHEMERIS_NAME          = EPHEMERIS SATELLITE A
COVARIANCE_METHOD       = CALCULATED
MANEUVERABLE            = YES
REF_FRAME               = EME2000
X                       = 2570.097065               [km]
Y                       = 2244.654904               [km]
Z                       = 6281.497978               [km]
X_DOT                   = 4.418769571               [km/s]
Y_DOT                   = 4.833547743               [km/s]
Z_DOT                   = -3.526774282              [km/s]
CR_R                    = 4.142E+01                 [m**2]
CT_R                    = -8.579E+00                [m**2]
CT_T                    = 2.533E+03                 [m**2]
CN_R                    = -2.313E+01                [m**2]
```

CN_T	= 1.336E+01	[m**2]
CN_N	= 7.098E+01	[m**2]
CRDOT_R	= 2.520E-03	[m**2/s]
CRDOT_T	= -5.476E+00	[m**2/s]
CRDOT_N	= 8.626E-04	[m**2/s]
CRDOT_RDOT	= 5.744E-03	[m**2/s**2]
CTDOT_R	= -1.006E-02	[m**2/s]
CTDOT_T	= 4.041E-03	[m**2/s]
CTDOT_N	= -1.359E-03	[m**2/s]
CTDOT_RDOT	= -1.502E-05	[m**2/s**2]
CTDOT_TDOT	= 1.049E-05	[m**2/s**2]
CNDOT_R	= 1.053E-03	[m**2/s]
CNDOT_T	= -3.412E-03	[m**2/s]
CNDOT_N	= 1.213E-02	[m**2/s]
CNDOT_RDOT	= -3.004E-06	[m**2/s**2]
CNDOT_TDOT	= -1.091E-06	[m**2/s**2]
CNDOT_NDOT	= 5.529E-05	[m**2/s**2]
OBJECT	= OBJECT2	
OBJECT_NUMBER	= 30337	
SAT_CATALOG	= SATCAT	
OBJECT_NAME	= FENGYUN 1C DEB	
OBJECT_ID	= 1999-025AA	
EPHEMERIS_NAME	= NONE	
COVARIANCE_METHOD	= CALCULATED	
MANEUVERABLE	= NO	
REF_FRAME	= EME2000	
X	= 2569.540800	[km]
Y	= 2245.093614	[km]
Z	= 6281.599946	[km]
X_DOT	= -2.888612500	[km/s]
Y_DOT	= -6.007247516	[km/s]
Z_DOT	= 3.328770172	[km/s]
CR_R	= 1.337E+03	[m**2]
CT_R	= -4.806E+04	[m**2]
CT_T	= 2.492E+06	[m**2]
CN_R	= -3.298E+01	[m**2]
CN_T	= -7.5888E+02	[m**2]
CN_N	= 7.105E+01	[m**2]
CRDOT_R	= 2.591E-03	[m**2/s]
CRDOT_T	= -4.152E-02	[m**2/s]
CRDOT_N	= -1.784E-06	[m**2/s]
CRDOT_RDOT	= 6.886E-05	[m**2/s**2]
CTDOT_R	= -1.016E-02	[m**2/s]
CTDOT_T	= -1.506E-04	[m**2/s]
CTDOT_N	= 1.637E-03	[m**2/s]
CTDOT_RDOT	= -2.987E-06	[m**2/s**2]
CTDOT_TDOT	= 1.059E-05	[m**2/s**2]
CNDOT_R	= 4.400E-03	[m**2/s]
CNDOT_T	= 8.482E-03	[m**2/s]
CNDOT_N	= 8.633E-05	[m**2/s]
CNDOT_RDOT	= -1.903E-06	[m**2/s**2]
CNDOT_TDOT	= -4.594E-06	[m**2/s**2]
CNDOT_NDOT	= 5.178E-05	[m**2/s**2]

Figure 3-1: An Example of a CDM in KVN With Only Obligatory Keywords

CCSDS_CDM_VERS	= 1.0	
CREATION_DATE	= 2010-03-12T22:31:12.000	
ORIGINATOR	= JSPOC	
CDM_FOR	= SATELLITE A	
MESSAGE_ID	= 201113719185	
COMMENT Relative Metadata/Data		
TCA	= 2010-03-13T22:37:52.618	
MISS_DISTANCE	= 715	[m]
RELATIVE_SPEED	= 14762	[m/s]
RELATIVE_POSITION_R	= 27.4	[m]
RELATIVE_POSITION_T	= -70.2	[m]
RELATIVE_POSITION_N	= 711.8	[m]
RELATIVE_VELOCITY_R	= -7.2	[m/s]
RELATIVE_VELOCITY_T	= -14692.0	[m/s]
RELATIVE_VELOCITY_N	= -1437.2	[m/s]
START_SCREEN_PERIOD	= 2010-03-12T18:29:32:212	
STOP_SCREEN_PERIOD	= 2010-03-15T18:29:32:212	
SCREEN_VOLUME_FRAME	= RTN	
SCREEN_VOLUME_SHAPE	= ELLIPSOID	
SCREEN_VOLUME_X	= 200	[m]
SCREEN_VOLUME_Y	= 1000	[m]
SCREEN_VOLUME_Z	= 1000	[m]
ENTRY_TIME	= 2010-03-13T20:25:43.222	
EXIT_TIME	= 2010-03-13T23:44:29.324	
COLLISION_PROBABILITY	= 4.835E-05	
COLLISION_PROBABILITY_METHOD	= FOSTER-1992	
COMMENT Object1 Metadata		
OBJECT	= OBJECT1	
OBJECT_NUMBER	= 12345	
SAT_CATALOG	= SATCAT	
OBJECT_NAME	= SATELLITE A	
OBJECT_ID	= 1997-030E	
OBJECT_TYPE	= PAYLOAD	
OPERATOR_CONTACT_POSITION	= OSA	
OPERATOR_ORGANIZATION	= EUMETSAT	
OPERATOR_PHONE	= +49615130312	
OPERATOR_EMAIL	= HANS.WALDVOGEL@EUMETSAT.INT	
EPHEMERIS_NAME	= EPHEMERIS SATELLITE A	
NUMBER_SENSORS	= 2	
TRACKING_DATA_TYPES	= GPS, DOPPLER	
ADDITIONAL_TRACKING	= YES	
COVARIANCE_METHOD	= CALCULATED	
MANEUVERABLE	= YES	
MAN_INCLUDED	= YES	
REF_FRAME	= EME2000	
GRAVITY_MODEL	= EGM-96: 36D 36O	
ATMOSPHERIC_MODEL	= JACCHIA 70 DCA	
N_BODY_PERTURBATIONS	= MOON, SUN	
SOLAR_RAD_ PRESSURE	= NO	
EARTH_TIDES	= NO	
INTRACK_THRUST	= NO	
COMMENT Object1 Data		
COMMENT Object1 OD Parameters		
TIME_LASTOB	= 2010-03-12T02:14:12.746	
RECOMMENDED_OD_SPAN	= 7.88	[d]

ACTUAL_OD_SPAN	= 5.50	[d]
MAXIMUM_OBS_GAP	= 2.4	[h]
OBS_AVAILABLE	= 592	
OBS_USED	= 418	
TRACKS_AVAILABLE	= 123	
TRACKS USED	= 98	
WEIGHTED_RMS	= 0.864	
TIME_NEXT_UPDATE	= 2.0	[h]
COMMENT Object1 Additional Parameters		
AREA	= 5.2	[m**2]
MASS	= 2516	[kg]
CD_AREA_OVER_MASS	= 0.045663	[m**2/kg]
CR_AREA_OVER_MASS	= 0.000000	[m**2/kg]
THRUST_ACCELERATION	= 0.0	[m/s**2]
SEDR	= 4.54570E-05	[W/kg]
COMMENT Object1 State Vector		
X	= 2570.097065	[km]
Y	= 2244.654904	[km]
Z	= 6281.497978	[km]
X_DOT	= 4.418769571	[km/s]
Y_DOT	= 4.833547743	[km/s]
Z_DOT	= -3.526774282	[km/s]
COMMENT Object1 Covariance in the RTN Coordinate Frame		
CR_R	= 4.142E+01	[m**2]
CT_R	= -8.579E+00	[m**2]
CT_T	= 2.533E+03	[m**2]
CN_R	= -2.313E+01	[m**2]
CN_T	= 1.336E+01	[m**2]
CN_N	= 7.098E+01	[m**2]
CRDOT_R	= 2.520E-03	[m**2/s]
CRDOT_T	= -5.476E+00	[m**2/s]
CRDOT_N	= 8.626E-04	[m**2/s]
CRDOT_RDOT	= 5.744E-03	[m**2/s**2]
CTDOT_R	= -1.006E-02	[m**2/s]
CTDOT_T	= 4.041E-03	[m**2/s]
CTDOT_N	= -1.359E-03	[m**2/s]
CTDOT_RDOT	= -1.502E-05	[m**2/s**2]
CTDOT_TDOT	= 1.049E-05	[m**2/s**2]
CNDOT_R	= 1.053E-03	[m**2/s]
CNDOT_T	= -3.412E-03	[m**2/s]
CNDOT_N	= 1.213E-02	[m**2/s]
CNDOT_RDOT	= -3.004E-06	[m**2/s**2]
CNDOT_TDOT	= -1.091E-06	[m**2/s**2]
CNDOT_NDOT	= 5.529E-05	[m**2/s**2]
COMMENT Object2 Metadata		
OBJECT	= OBJECT2	
OBJECT_NUMBER	= 30337	
SAT_CATALOG	= SATCAT	
OBJECT_NAME	= FENGYUN 1C DEB	
OBJECT_ID	= 1999-025AA	
OBJECT_TYPE	= DEBRIS	
EPHEMERIS_NAME	= NONE	
NUMBER_SENSORS	= 3	
TRACKING_DATA_TYPES	= RADAR	
ADDITIONAL_TRACKING	= NO	
COVARIANCE_METHOD	= CALCULATED	

MANEUVERABLE	= NO	
REF_FRAME	= EME2000	
GRAVITY_MODEL	= EGM-96: 36D 36O	
ATMOSPHERIC_MODEL	= JACCHIA 70 DCA	
N_BODY_PERTURBATIONS	= MOON, SUN	
SOLAR_RAD_ PRESSURE	= YES	
EARTH_TIDES	= NO	
INTRACK_THRUST	= NO	
COMMENT Object2 Data		
COMMENT Object2 OD Parameters		
TIME_LASTOB	= 6-12	[h]
RECOMMENDED_OD_SPAN	= 2.63	[d]
ACTUAL_OD_SPAN	= 2.63	[d]
MAXIMUM_OBS_GAP	= 5.7	[h]
OBS_AVAILABLE	= 59	
OBS_USED	= 58	
TRACKS_AVAILABLE	= 15	
TRACKS USED	= 15	
WEIGHTED_RMS	= 0.864	
COMMENT Object2 Additional Parameters		
AREA	= 0.9	[m**2]
CD_AREA_OVER_MASS	= 0.118668	[m**2/kg]
CR_AREA_OVER_MASS	= 0.075204	[m**2/kg]
THRUST_ACCELERATION	= 0.0	[m/s**2]
SEDR	= 5.40900E-03	[W/kg]
COMMENT Object2 State Vector		
X	= 2569.540800	[km]
Y	= 2245.093614	[km]
Z	= 6281.599946	[km]
X_DOT	= -2.888612500	[km/s]
Y_DOT	= -6.007247516	[km/s]
Z_DOT	= 3.328770172	[km/s]
COMMENT Object2 Covariance in the RTN Coordinate Frame		
CR_R	= 1.337E+03	[m**2]
CT_R	= -4.806E+04	[m**2]
CT_T	= 2.492E+06	[m**2]
CN_R	= -3.298E+01	[m**2]
CN_T	= -7.5888E+02	[m**2]
CN_N	= 7.105E+01	[m**2]
CRDOT_R	= 2.591E-03	[m**2/s]
CRDOT_T	= -4.152E-02	[m**2/s]
CRDOT_N	= -1.784E-06	[m**2/s]
CRDOT_RDOT	= 6.886E-05	[m**2/s**2]
CTDOT_R	= -1.016E-02	[m**2/s]
CTDOT_T	= -1.506E-04	[m**2/s]
CTDOT_N	= 1.637E-03	[m**2/s]
CTDOT_RDOT	= -2.987E-06	[m**2/s**2]
CTDOT_TDOT	= 1.059E-05	[m**2/s**2]
CNDOT_R	= 4.400E-03	[m**2/s]
CNDOT_T	= 8.482E-03	[m**2/s]
CNDOT_N	= 8.633E-05	[m**2/s]
CNDOT_RDOT	= -1.903E-06	[m**2/s**2]
CNDOT_TDOT	= -4.594E-06	[m**2/s**2]
CNDOT_NDOT	= 5.178E-05	[m**2/s**2]

Figure 3-2: An Example of a CDM in KVN Which Includes Optional Keywords

CCSDS_CDM_VERS	= 1.0	
CREATION_DATE	= 2012-01-12T22:31:12.000	
ORIGINATOR	= SDC	
CDM_FOR	= GALAXY 15	
MESSAGE_ID	= 20120112223112	
COMMENT Relative Metadata/Data		
TCA	= 2012-12-13T22:37:52.618	
MISS_DISTANCE	= 104.92	[m]
RELATIVE_SPEED	= 12093.52	[m/s]
RELATIVE_POSITION_R	= 30.6	[m]
RELATIVE_POSITION_T	= 100.2	[m]
RELATIVE_POSITION_N	= 5.7	[m]
RELATIVE_VELOCITY_R	= -20.3	[m/s]
RELATIVE_VELOCITY_T	= -12000.0	[m/s]
RELATIVE_VELOCITY_N	= -1500 .9	[m/s]
START_SCREEN_PERIOD	= 2012-09-12T18:29:32:212	
STOP_SCREEN_PERIOD	= 2012-16-15T18:29:32:212	
SCREEN_VOLUME_FRAME	= RTN	
SCREEN_VOLUME_SHAPE	= ELLIPSOID	
SCREEN_VOLUME_X	= 500	[m]
SCREEN_VOLUME_Y	= 500	[m]
SCREEN_VOLUME_Z	= 500	[m]
ENTRY_TIME	= 2012-12-13T20:25:43.222	
EXIT_TIME	= 2010-12-13T23:44:29.324	
COLLISION_PROBABILITY	= 2.355e-03	
COLLISION_PROBABILITY_METHOD	= ALFANO-2005	
COMMENT Object1 Metadata		
OBJECT	= OBJECT1	
OBJECT_NUMBER	= 28884	
SAT_CATALOG	= SATCAT	
OBJECT_NAME	= GALAXY 15	
OBJECT_ID	= 2005-041A	
OBJECT_TYPE	= PAYLOAD	
OPERATOR_ORGANIZATION	= INTELSAT	
EPHEMERIS_NAME	= GALAXY-15A-2012JAN-WMANEUVER23A	
COVARIANCE_METHOD	= CALCULATED	
MANEUVERABLE	= YES	
MAN_INCLUDED	= YES	
REF_FRAME	= EME2000	
COMMENT Object1 Data		
COMMENT Object1 OD Parameters		
TIME_LASTOB	= 2012-09-06T20:25:43.222	
X	= -41600.46272465	[km]
Y	= 3626.912120064	[km]
Z	= 6039.06350924	[km]
X_DOT	= -0.306132852503	[km/s]
Y_DOT	= -3.044998353334	[km/s]
Z_DOT	= -0.287674310725	[km/s]
COMMENT Object1 Covariance in the RTN Coordinate Frame		
CR_R	= 4.142E+01	
CT_R	= -8.579E+00	[m**2]
CT_T	= 2.533E+03	[m**2]
CN_R	= -2.313E+01	[m**2]

CN_T	= 1.336E+01	[m**2]
CN_N	= 7.098E+01	[m**2]
CRDOT_R	= 2.520E-03	[m**2/s]
CRDOT_T	= -5.476E+00	[m**2/s]
CRDOT_N	= 8.626E-04	[m**2/s]
CRDOT_RDOT	= 5.744E-03	[m**2/s**2]
CTDOT_R	= -1.006E-02	[m**2/s]
CTDOT_T	= 4.041E-03	[m**2/s]
CTDOT_N	= -1.359E-03	[m**2/s]
CTDOT_RDOT	= -1.502E-05	[m**2/s**2]
CTDOT_TDOT	= 1.049E-05	[m**2/s**2]
CNDOT_R	= 1.053E-03	[m**2/s]
CNDOT_T	= -3.412E-03	[m**2/s]
CNDOT_N	= 1.213E-02	[m**2/s]
CNDOT_RDOT	= -3.004E-06	[m**2/s**2]
CNDOT_TDOT	= -1.091E-06	[m**2/s**2]
CNDOT_NDOT	= 5.529E-05	[m**2/s**2]
COMMENT Object2 Metadata		
OBJECT	= OBJECT2	
OBJECT_NUMBER	= 21139	
SAT_CATALOG	= SATCAT	
OBJECT_NAME	= ASTRA 1B	
OBJECT_ID	= 1991-051A	
OBJECT_TYPE	= PAYLOAD	
EPHEMERIS_NAME	= NONE	
ADDITIONAL_TRACKING	= YES	
COVARIANCE_METHOD	= CALCULATED	
MANEUVERABLE	= YES	
REF_FRAME	= EME2000	
COMMENT Object1 Data		
COMMENT Object1 OD Parameters		
TIME_LASTOB	= 2012-08-03T10:22:14.548	
X	= -2956.02034826	[km]
Y	= 42584.37595741	[km]
Z	= 123.77550476	[km]
X_DOT	= -3.047096589536	[km/s]
Y_DOT	= -0.211583631026	[km/s]
Z_DOT	= 0.062261259643	[km/s]
COMMENT Object2 Covariance in the RTN Coordinate Frame		
CR_R	= 1.337E+03	[m**2]
CT_R	= -4.806E+04	[m**2]
CT_T	= 2.492E+06	[m**2]
CN_R	= -3.298E+01	[m**2]
CN_T	= -7.5888E+02	[m**2]
CN_N	= 7.105E+01	[m**2]
CRDOT_R	= 2.591E-03	[m**2/s]
CRDOT_T	= -4.152E-02	[m**2/s]
CRDOT_N	= -1.784E-06	[m**2/s]
CRDOT_RDOT	= 6.886E-05	[m**2/s**2]
CTDOT_R	= -1.016E-02	[m**2/s]
CTDOT_T	= -1.506E-04	[m**2/s]
CTDOT_N	= 1.637E-03	[m**2/s]
CTDOT_RDOT	= -2.987E-06	[m**2/s**2]
CTDOT_TDOT	= 1.059E-05	[m**2/s**2]
CNDOT_R	= 4.400E-03	[m**2/s]

CNDOT_T	= 8.482E-03	[m**2/s]
CNDOT_N	= 8.633E-05	[m**2/s]
CNDOT_RDOT	= -1.903E-06	[m**2/s**2]
CNDOT_TDOT	= -4.594E-06	[m**2/s**2]
CNDOT_NDOT	= 5.178E-05	[m**2/s**2]

Figure 3-3: Another Example of a CDM in KVN Which Includes Optional Keywords

4 CDM CONTENT/STRUCTURE IN XML

4.1 THE CDM/XML SCHEMA

The CDM/XML schema shall be available on SANA, which is the registrar function for the protocol registries created under CCSDS. The CDM XML schema explicitly defines the permitted data elements and values acceptable for the XML version of the CDM message.

The location of the CDM/XML schema will be:

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

Where possible this schema uses simple types and complex types used by the constituent schemas that make up Navigation Data Messages (NDM) (AEM, APM, OEM, OMM, OPM, TDM). An example CDM/XML schema is currently referenced in Annex F of this document. Once this document is finalized, Annex F will be removed. This will allow updates of the schema on the web site without correspondingly updating the CDM document.

4.2 CDM/XML BASIC STRUCTURE

4.2.1 Each CDM shall consist of a <header> and a <body>.

4.2.2 The CDM body shall consist of exactly two segment constructs.

4.2.3 Each <segment> shall consist of a <metadata>/<data> pair, as shown in Figure 4-1.

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

Figure 4-1: CDM XML Basic Structure

4.2.4 KVN keywords shall be uppercase with '_' as separators. XML tags shall be uppercase and correspond with the keywords in sections 3.2 through 3.6. The XML logical tags related to message structure shall be in lowerCamelCase.

4.3 CONSTRUCTING A CDM/XML INSTANCE

4.3.1 OVERVIEW

This section provides more detailed instructions for the user on how to create an XML message based on the ASCII-text KVN-formatted message described in sections 3.1 through 3.6 (See reference [6]).

4.3.2 XML VERSION

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

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

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

4.3.3 BEGINNING THE INSTANTIATION: ROOT DATA ELEMENT

4.3.3.1 A CDM instantiation shall be delimited with the <cdm></cdm> root element tags using the standard attributes documented in reference [3].

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

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

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

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

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

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

4.3.3.4 If a local version is used, the value associated with the xsi:noNamespaceSchemaLocation attribute must be changed to a URL that is accessible to the local server.

4.3.3.5 The final attributes of the <cdm> tag shall be 'id' and 'version'.

4.3.3.6 The 'id' attribute shall be 'id="CCSDS_CDM_VERS" '.

4.3.3.7 The 'version' attribute shall be 'version="1.0" '.

4.3.3.8 The following example root element tag for a CDM instantiation combines all the directions in the preceding several subsections:

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

4.3.4 THE CDM/XML HEADER SECTION

4.3.4.1 The CDM has a standard header format, with tags <header> and </header>.

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

4.3.4.3 The standard CDM header shall contain the following element tags:

a) <CREATION_DATE>

b) <ORIGINATOR>

c) <CDM_FOR>

d) <MESSAGE_ID>

The rules for these keywords are specified in section 3.2. The header would look like this:

```
<header>
  <COMMENT>Some comment string.</COMMENT>
  <CREATION_DATE>2010-03-12T22:31:12.000</CREATION_DATE>
  <ORIGINATOR>JSpOC</ORIGINATOR>
  <CDM_FOR>SATELLITE A</CDM_FOR>
  <MESSAGE_ID>201113719185</MESSAGE_ID>
</header>
```

4.3.5 THE CDM/XML BODY SECTION

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

4.3.5.2 Inside the <body></body> tag pair must appear one <relativeMetadataData></relativeMetadataData> tag pair.

4.3.5.3 Following the <relativeMetadataData></relativeMetadataData> tag pair must appear two tag pairs, one for Object1 and one for Object2.

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

4.3.6 THE CDM/XML RELATIVE METADATA/DATA SECTION

The relative metadata/data section shall be set off by the <relativeMetadataData></relativeMetadataData> tag combination. Between the <relativeMetadataData> and </relativeMetadataData> tags, the keywords shall be the same as specified in Table 3-2.

4.3.7 THE CDM/XML METADATA SECTION

4.3.7.1 All CDMs must have two metadata sections, one for Object1 and one for Object2.

4.3.7.2 The metadata section for Object1 shall follow the relative metadata/data section and shall be set off by the <metadata></metadata> tag combination. The metadata section for Object2 shall follow the Object1 data section and shall be set off by the <metadata ></metadata> tag combination.

4.3.7.3 Between the <metadata> and </metadata> tags for both Object1 and Object2, the keywords shall be the same as specified in Table 3-3. The value of the keyword OBJECT will be used to define whether the metadata defines Object1 or Object2.

4.3.8 THE CDM DATA SECTION

4.3.8.1 All CDMs must have two data sections, one for Object1 and one for Object2.

4.3.8.2 Each data section shall follow the corresponding metadata section and shall be set off by the <data></data> tag combination.

4.3.8.3 Between the <data> and </data> tags, the keywords shall be the same as specified in Table 3-4. The value of the keyword OBJECT, referenced in Table 3-3, will be used to define whether the data defines Object1 or Object2.

4.3.9 SPECIAL CDM/XML TAGS

4.3.9.1 The information content in the CDM is separated into constructs described in section 3.5 as ‘logical blocks’. Special tags in the CDM shall be used to encapsulate the information in the logical blocks of the CDM. The following CDM/XML tags are defined:

Table 4-1: Relation of KVN Logical Blocks to Special CDM/XML Tags

CDM Logical Block	Associated CDM/XML Tag
OD Parameters	<odParameters>
Additional Parameters	<additionalParameters>
State Vector	<stateVector>
Covariance Matrix	<covarianceMatrix>

4.3.9.2 Other special tags are defined:

Table 4-2: Other Special CDM/XML Tags

Special Tag	Definition
<relativeStateVector>	Includes the relative state vector keywords: RELATIVE_POSITION_R, RELATIVE_POSITION_T, RELATIVE_POSITION_N, RELATIVE_VELOCITY_R, RELATIVE_VELOCITY_T, and RELATIVE_VELOCITY_N.
<lastObAt>	The TIME_LASTOB entered as the exact time (see Table 3-4, TIME_LASTOB).
<timeSince>	The TIME_LASTOB entered as an elapsed time, from the message creation time, that includes the time of the last accepted observation used in the OD of the object (see Table 3-4, TIME_LASTOB).

4.3.10 UNITS IN THE CDM/XML

The units in the CDM/XML shall be the same units used in the KVN-formatted CDM which are described in section 3.5. XML attributes are used to explicitly define the units or other important information associated with the given data element.

4.4 CDM/XML EXAMPLE

The following is a sample of a CDM in XML format:

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

  <header>
    <COMMENT>Sample CDM - XML version</COMMENT>
    <CREATION_DATE>2010-03-12T22:31:12.000</CREATION_DATE>
    <ORIGINATOR>JSPOC</ORIGINATOR>
    <CDM_FOR>SATELLITE A</CDM_FOR>
    <MESSAGE_ID>20111371985</MESSAGE_ID>
  </header>
  <body>
    <relativeMetadataData>
      <COMMENT>Relative Metadata/Data</COMMENT>
      <TCA>2010-03-13T22:37:52.618</TCA>
      <MISS_DISTANCE units="m">715</MISS_DISTANCE>
      <RELATIVE_SPEED units="m/s">14762</RELATIVE_SPEED>
      <relativeStateVector>
        <RELATIVE_POSITION_R units="m">27.4</RELATIVE_POSITION_R>
        <RELATIVE_POSITION_T units="m">-70.2</RELATIVE_POSITION_T>
        <RELATIVE_POSITION_N units="m">711.8</RELATIVE_POSITION_N>
        <RELATIVE_VELOCITY_R units="m/s">-7.2</RELATIVE_VELOCITY_R>
        <RELATIVE_VELOCITY_T units="m/s">-14692.0</RELATIVE_VELOCITY_T>
        <RELATIVE_VELOCITY_N units="m/s">-1437.2</RELATIVE_VELOCITY_N>
      </relativeStateVector>
      <START_SCREEN_PERIOD>2010-03-12T18:29:32.212</START_SCREEN_PERIOD>
      <STOP_SCREEN_PERIOD>2010-03-15T18:29:32.212</STOP_SCREEN_PERIOD>
      <SCREEN_VOLUME_FRAME>RTN</SCREEN_VOLUME_FRAME>
      <SCREEN_VOLUME_SHAPE>ELLIPSOID</SCREEN_VOLUME_SHAPE>
      <SCREEN_VOLUME_X units="m">200</SCREEN_VOLUME_X>
      <SCREEN_VOLUME_Y units="m">1000</SCREEN_VOLUME_Y>
      <SCREEN_VOLUME_Z units="m">1000</SCREEN_VOLUME_Z>
      <ENTRY_TIME>2010-03-13T20:25:43.222</ENTRY_TIME>
      <EXIT_TIME>2010-03-13T23:44:29.324</EXIT_TIME>
      <COLLISION_PROBABILITY>4.835E-05</COLLISION_PROBABILITY>
      <COLLISION_PROBABILITY_METHOD>FOSTER-1992</COLLISION_PROBABILITY_METHOD>
    </relativeMetadataData>
    &lt;segment&gt;
      <metadata>
        <COMMENT>Object1 Metadata</COMMENT>
        <OBJECT>OBJECT1</OBJECT>
        <OBJECT_NUMBER>12345</OBJECT_NUMBER>
        <SAT_CATALOG>SATCAT</SAT_CATALOG>
        <OBJECT_NAME>SATELLITE A</OBJECT_NAME>
        <OBJECT_ID>1997-030E</OBJECT_ID>
        <OBJECT_TYPE>PAYLOAD</OBJECT_TYPE>
        <OPERATOR_CONTACT_POSITION>OSA</OPERATOR_CONTACT_POSITION>
        <OPERATOR_ORGANIZATION>EUMETSAT</OPERATOR_ORGANIZATION>
        <OPERATOR_PHONE>+49615130312</OPERATOR_PHONE>
        <OPERATOR_EMAIL>HANS.WALDVOGEL@EUMETSAT.INT</OPERATOR_EMAIL>
        <EPHEMERIS_NAME>EPHEMERIS SATELLITE A</EPHEMERIS_NAME>
        <NUMBER_SENSORS>2</NUMBER_SENSORS>
        <TRACKING_DATA_TYPES>GPS,DOPPLER</TRACKING_DATA_TYPES>
        <ADDITIONAL_TRACKING>YES</ADDITIONAL_TRACKING>
        <COVARIANCE_METHOD>CALCULATED</COVARIANCE_METHOD>
```

```
    <MANEUVERABLE>YES</MANEUVERABLE>
    <MAN_INCLUDED>YES</MAN_INCLUDED>
    <REF_FRAME>EME2000</REF_FRAME>
    <GRAVITY_MODEL>EGM-96: 36D 36O</GRAVITY_MODEL>
    <ATMOSPHERIC_MODEL>JACCHIA 70 DCA</ATMOSPHERIC_MODEL>
    <N_BODY_PERTURBATIONS>MOON,SUN</N_BODY_PERTURBATIONS>
    <SOLAR_RAD_PRESSURE>NO</SOLAR_RAD_PRESSURE>
    <EARTH_TIDES>NO</EARTH_TIDES>
    <INTRACK_THRUST>NO</INTRACK_THRUST>
  </metadata>
  <data>
    <COMMENT>Object1 Data</COMMENT>
    <odParameters>
      <COMMENT>Object1 OD Parameters</COMMENT>
      <TIME_LASTOB>
        <lastObAt>2010-03-12T02:14:12.746</lastObAt>
      </TIME_LASTOB>
      <RECOMMENDED_OD_SPAN units="d">7.88</RECOMMENDED_OD_SPAN>
      <ACTUAL_OD_SPAN units="d">5.50</ACTUAL_OD_SPAN>
      <MAXIMUM_OBS_GAP units="h">2.4</MAXIMUM_OBS_GAP>
      <OBS_AVAILABLE>592</OBS_AVAILABLE>
      <OBS_USED>418</OBS_USED>
      <TRACKS_AVAILABLE>123</TRACKS_AVAILABLE>
      <TRACKS_USED>98</TRACKS_USED>
      <WEIGHTED_RMS>0.864</WEIGHTED_RMS>
      <TIME_NEXT_UPDATE units="h">2.0</TIME_NEXT_UPDATE>
    </odParameters>
    <additionalParameters>
      <COMMENT>Object 1 Additional Parameters</COMMENT>
      <AREA units="m**2">5.2</AREA>
      <MASS units="kg">2516</MASS>
      <CD_AREA_OVER_MASS units="m**2/kg">0.045663</CD_AREA_OVER_MASS>
      <CR_AREA_OVER_MASS units="m**2/kg">0.000000</CR_AREA_OVER_MASS>
      <THRUST_ACCELERATION units="m/s**2">0.0</THRUST_ACCELERATION>
      <SEDR units="W/kg">4.54570E-05</SEDR>
    </additionalParameters>
    <stateVector>
      <COMMENT>Object1 State Vector</COMMENT>
      <X units="km">2570.097065</X>
      <Y units="km">2244.654904</Y>
      <Z units="km">6281.497978</Z>
      <X_DOT units="km/s">4.418769571</X_DOT>
      <Y_DOT units="km/s">4.833547743</Y_DOT>
      <Z_DOT units="km/s">-3.526774282</Z_DOT>
    </stateVector>
    <covarianceMatrix>
      <COMMENT>Object1 Covariance in the RTN Coordinate Frame </COMMENT>
      <CR_R units="m**2">4.142E+01</CR_R>
      <CT_R units="m**2">-8.579E+00</CT_R>
      <CT_T units="m**2">2.533E+03</CT_T>
      <CN_R units="m**2">-2.313E+01</CN_R>
      <CN_T units="m**2">1.336E+01</CN_T>
      <CN_N units="m**2">7.098E+01</CN_N>
      <CRDOT_R units="m**2/s">2.520E-03</CRDOT_R>
      <CRDOT_T units="m**2/s">-5.476E+00</CRDOT_T>
      <CRDOT_N units="m**2/s">8.626E-04</CRDOT_N>
```

```
      <CRDOT_RDOT units="m**2/s**2">5.744E-03</CRDOT_RDOT>
      <CTDOT_R units="m**2/s">-1.006E-02</CTDOT_R>
      <CTDOT_T units="m**2/s">4.041E-03</CTDOT_T>
      <CTDOT_N units="m**2/s">-1.359E-03</CTDOT_N>
      <CTDOT_RDOT units="m**2/s**2">-1.502E-05</CTDOT_RDOT>
      <CTDOT_TDOT units="m**2/s**2">1.049E-05</CTDOT_TDOT>
      <CNDOT_R units="m**2/s">1.053E-03</CNDOT_R>
      <CNDOT_T units="m**2/s">-3.412E-03</CNDOT_T>
      <CNDOT_N units="m**2/s">1.213E-02</CNDOT_N>
      <CNDOT_RDOT units="m**2/s**2">-3.004E-06</CNDOT_RDOT>
      <CNDOT_TDOT units="m**2/s**2">-1.091E-06</CNDOT_TDOT>
      <CNDOT_NDOT units="m**2/s**2">5.529E-05</CNDOT_NDOT>
    </covarianceMatrix>
  </data>
&lt;/segment&gt;
&lt;segment&gt;
  <metadata>
    <COMMENT>Object2 Metadata</COMMENT>
    <OBJECT>OBJECT2</OBJECT>
    <OBJECT_NUMBER>30337</OBJECT_NUMBER>
    <SAT_CATALOG>SATCAT</SAT_CATALOG>
    <OBJECT_NAME>FENGYUN 1C DEB</OBJECT_NAME>
    <OBJECT_ID>1999-025AA</OBJECT_ID>
    <OBJECT_TYPE>DEBRIS</OBJECT_TYPE>
    <EPHEMERIS_NAME>NONE</EPHEMERIS_NAME>
    <NUMBER_SENSORS>3</NUMBER_SENSORS>
    <TRACKING_DATA_TYPES>RADAR</TRACKING_DATA_TYPES>
    <ADDITIONAL_TRACKING>NO</ADDITIONAL_TRACKING>
    <COVARIANCE_METHOD>CALCULATED</COVARIANCE_METHOD>
    <MANEUVERABLE>NO</MANEUVERABLE>
    <REF_FRAME>EME2000</REF_FRAME>
    <GRAVITY_MODEL>EGM-96: 36D 36O</GRAVITY_MODEL>
    <ATMOSPHERIC_MODEL>JACCHIA 70 DCA</ATMOSPHERIC_MODEL>
    <N_BODY_PERTUBATIONS>MOON,SUN</N_BODY_PERTUBATIONS>
    <SOLAR_RAD_PRESSURE>YES</SOLAR_RAD_PRESSURE>
    <EARTH_TIDES>NO</EARTH_TIDES>
    <INTRACK_THRUST>NO</INTRACK_THRUST>
  </metadata>
  <data>
    <COMMENT>Object2 Data</COMMENT>
    <odParameters>
      <COMMENT>Object2 OD Parameters</COMMENT>
      <TIME_LASTOB>
        <timeSince units="h">6-12</timeSince>
      </TIME_LASTOB>
      <RECOMMENDED_OD_SPAN units="d">2.63</RECOMMENDED_OD_SPAN>
      <ACTUAL_OD_SPAN units="d">2.63</ACTUAL_OD_SPAN>
      <MAXIMUM_OBS_GAP units="h">5.7</MAXIMUM_OBS_GAP>
      <OBS_AVAILABLE>59</OBS_AVAILABLE>
      <OBS_USED>58</OBS_USED>
      <TRACKS_AVAILABLE>15</TRACKS_AVAILABLE>
      <TRACKS_USED>15</TRACKS_USED>
      <WEIGHTED_RMS>0.864</WEIGHTED_RMS>
    </odParameters>
    <additionalParameters>
      <COMMENT>Object2 Additional Parameters</COMMENT>
```

```
        <AREA units="m**2">0.9</AREA>
        <CD_AREA_OVER_MASS units="m**2/kg">0.118668</CD_AREA_OVER_MASS>
        <CR_AREA_OVER_MASS units="m**2/kg">0.075204</CR_AREA_OVER_MASS>
        <THRUST_ACCELERATION units="m/s**2">0.0</THRUST_ACCELERATION>
        <SEDR units="W/kg">5.40900E-03</SEDR>
      </additionalParameters>
      <stateVector>
        <COMMENT>Object2 State Vector</COMMENT>
        <X units="km">2569.540800</X>
        <Y units="km">2245.093614</Y>
        <Z units="km">6281.599946</Z>
        <X_DOT units="km/s">-2.888612500</X_DOT>
        <Y_DOT units="km/s">-6.007247516</Y_DOT>
        <Z_DOT units="km/s">3.328770172</Z_DOT>
      </stateVector>
      <covarianceMatrix>
        <COMMENT>Object2 Covariance in the RTN Coordinate Frame</COMMENT>
        <CR_R units="m**2">1.337E+03</CR_R>
        <CT_R units="m**2">-4.806E+04</CT_R>
        <CT_T units="m**2">2.492E+06</CT_T>
        <CN_R units="m**2">-3.298E+01</CN_R>
        <CN_T units="m**2">-7.5888E+02</CN_T>
        <CN_N units="m**2">7.105E+01</CN_N>
        <CRDOT_R units="m**2/s">2.591E-03</CRDOT_R>
        <CRDOT_T units="m**2/s">-4.152E-02</CRDOT_T>
        <CRDOT_N units="m**2/s">-1.784E-06</CRDOT_N>
        <CRDOT_RDOT units="m**2/s**2">6.886E-05</CRDOT_RDOT>
        <CTDOT_R units="m**2/s">-1.016E-02</CTDOT_R>
        <CTDOT_T units="m**2/s">-1.506E-04</CTDOT_T>
        <CTDOT_N units="m**2/s">1.637E-03</CTDOT_N>
        <CTDOT_RDOT units="m**2/s**2">-2.987E-06</CTDOT_RDOT>
        <CTDOT_TDOT units="m**2/s**2">1.059E-05</CTDOT_TDOT>
        <CNDOT_R units="m**2/s">4.400E-03</CNDOT_R>
        <CNDOT_T units="m**2/s">8.482E-03</CNDOT_T>
        <CNDOT_N units="m**2/s">8.633E-05</CNDOT_N>
        <CNDOT_RDOT units="m**2/s**2">-1.903E-06</CNDOT_RDOT>
        <CNDOT_TDOT units="m**2/s**2">-4.594E-06</CNDOT_TDOT>
        <CNDOT_NDOT units="m**2/s**2">5.178E-05</CNDOT_NDOT>
      </covarianceMatrix>
    </data>
  &lt;/segment&gt;
 </body>
</cdm>
```


Figure 4-2: An Example of a CDM in XLM Format

5 CDM DATA IN GENERAL

5.1 RULES THAT APPLY IN KVN AND XML

The following rules apply for both KVN and XML formatted CDMs.

5.1.1 Some keywords represent obligatory items and some are optional. KVN and XML assignments representing optional items may be omitted.

5.1.2 The objects' state vectors and covariance are given 'at the time of closest approach (TCA)', i.e., at the time specified in the TCA keyword.

5.1.3 Table 3-4 is broken into four logical blocks, each of which has a descriptive heading. These descriptive headings shall not be included in a CDM, unless they appear in a properly formatted COMMENT statement for the KVN implementation and values between the <COMMENT> and </COMMENT> tags for the XML implementation.

5.1.4 If $C_R \bullet A/m$, CR_AREA_OVER_MASS, is set to zero, no solar radiation pressure was taken into account in the orbit determination process.

5.1.5 If $C_D \bullet A/m$, CD_AREA_OVER_MASS, is set to zero, no atmospheric drag was taken into account in the orbit determination process.

5.1.6 If the acceleration due to in-track thrust, THRUST_ACCELERATION, is set to zero, no in-track thrust acceleration was taken into account in the orbit determination process.

5.1.7 Values in the covariance matrix shall be presented sequentially from upper left [1,1] to lower right [9,9], lower triangular form, row by row left to right. Variance and covariance values shall be expressed in standard double precision as related in 6.2.2.5.

5.1.8 The covariance matrix is obligatory for the position and velocity terms, given in the lower triangular form of a 6x6 matrix. Optional terms for CD_AREA_OVER_MASS (denoted 'DRG'), CR_AREA_OVER_MASS (denoted 'SRP'), and THRUST_ACCELERATION (denoted 'THR') should to be added to the 6x6 matrix, in the lower triangular form, to complete a 9x9 matrix. If any element in any of these rows (7, 8, or 9) is provided, then all of the elements for that row must be provided (i.e., a subset of the terms for any of these rows is not allowed). The purpose for providing the 7, 8 and 9 terms is so that users, who have the propagator model available, can correctly propagate the 6x6 position and velocity covariance to another time point.

6 CDM SYNTAX

6.1 OVERVIEW

This section details the syntax requirements for the CDM using both KVN and XML formats.

6.2 THE CDM IN KVN

6.2.1 CDM LINES IN KVN

6.2.1.1 Each CDM file shall consist of a set of CDM lines. Each CDM line shall be one of the following:

– Header line;

- Relative Metadata/Data line;

– Metadata line;

– Data line; or

– Blank line.

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

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

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

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

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

6.2.1.7 All header, relative metadata/data, metadata, and data lines shall use ‘keyword = value’ notation. For this purpose, only those keywords shown in table 3-1, table 3-2, table 3-3 and table 3-4 shall be used in a CDM.

6.2.1.8 Some keywords represent obligatory items and some are optional. KVN assignments representing optional items may be omitted.

6.2.1.9 Only a single ‘keyword = value’ assignment shall be made on a line.

6.2.1.10 Keywords must be uppercase and must not contain blanks.

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

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

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

6.2.1.14 The order of occurrence of obligatory and optional KVN assignments shall be fixed as shown in the tables in section 3 that describe the CDM keywords.

6.2.2 CDM VALUES IN KVN

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

6.2.2.2 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., $-2^{31} <= x <= 2^{31}-1$).

Note: The commas are listed in the range of values above only for ease of readability.

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

6.2.2.4 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.

6.2.2.5 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.

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

6.2.2.7 Blanks shall not be permitted within numeric values.

6.2.2.8 Time strings must follow the specified formats in section 6.2.2.11.

6.2.2.9 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.

6.2.2.10 All time tags in the CDM shall be in UTC.

6.2.2.11 In value fields that represent a time tag, times shall be given in one of the following two formats:

*yyyy-mm-dd***T***hh:mm:ss*[*.d→d*]

or

*yyyy-ddd***T***hh:mm:ss*[*.d→d*]

where '*yyyy*' is the year, '*mm*' is the two-digit month, '*dd*' is the two-digit day-of-month and '*ddd*' is the three-digit day of the year, separated by hyphens, '**T**' is a fixed separator between the date and time portions of the string, and '*hh:mm:ss*[*.d→d*]' is the time in hours, minutes, seconds and fractional seconds, separated by colons. As many 'd' characters to the right of the period as required may be used to obtain the required precision, up to the maximum allowed for a fixed point number. Because all times in the CDM are UTC, the "Z" indicator allowed by the CCSDS Time Codes standard should be omitted. All fields require leading zeros. (See reference [5], ASCII Time Code A or B).

6.2.2.12 In the value fields that represent TIME_LASTOB, a choice of data types is given that includes the exact time (See 6.2.2.11 for formatting rules) or an elapsed time, from the message creation time, since the last observation used in the OD of the object. When the elapsed time option is chosen, the notation "<", "-", and ">" will be used. The "<" means "less than" as in "< 6" means "less than six hours". The "-" means "to" as in "6 -12" means "six to twelve hours". The ">" means "greater than" as in "> 12" means "greater than twelve hours".

6.2.3 CDM UNITS IN KVN

6.2.3.1 If units are applicable, as specified in table 3-2 and/or table 3-4, they must be displayed and must exactly match the units specified in table 3-2 and table 3-4 (including case). When 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) multiplication of units shall be denoted with a single asterisk '*' (e.g., '[kg*s]');

d) exponents of units shall be denoted with a double asterisk (i.e., '**', for example, m/s^2 = m/s**2).

6.2.3.2 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 COLLISION_PROBABILITY, WEIGHTED_RMS). The notation '[n/a]' shall not appear in a CDM.

6.2.4 CDM COMMENTS IN KVN

6.2.4.1 For the CDM comment lines shall be optional.

6.2.4.2 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.

6.2.4.3 Placement of comments shall be as specified in the tables in section 3 that describe the CDM keywords.

6.3 THE CDM IN XML

6.3.1 CDM LINES IN XML

6.3.1.1 Each CDM file shall consist of a set of CDM lines. Each CDM line shall be one of the following:

– XML version line;

–An XML formatted data line; or

– Blank line.

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

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

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

6.3.1.5 The first line in the instantiation shall specify the XML version.

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

6.3.1.7 While specific formatting of an XML message is not critical, and white space and line breaks are not significant, it is suggested that the message should be organized and formatted to facilitate human comprehension.

6.3.2 CDM VALUES IN XML

6.3.2.1 Each obligatory XML tag must be present and contain a meaningful value.

6.3.2.2 Integer values shall follow the conventions of the *integer* data type per reference [4]. Additional restrictions on the allowable range or values permitted for any integer data element may also be defined in the CDM XML Schema. Examples of such restrictions may include a defined range (e.g., 0 - 100, 1 - 10, etc.) , a set of enumerated values (e.g., 0,1,2,4,8), a pre-defined specific variation such as *positiveInteger*, or a user-defined data type variation.

6.3.2.3 Non-integer numeric values may be expressed in either fixed-point or floating-point notation. Numeric values shall follow the conventions of the *double* data type per reference [4]. Additional restrictions on the allowable range or values permitted for any numeric data element may also be defined in the CDM XML Schema. Examples of such restrictions may include a defined range (e.g., 0.0 - 100.0, etc.), or a user-defined data type variation.

6.3.2.4 Text value data shall follow the conventions of the *string* data type per reference [4]. Additional restrictions on the allowable range or values permitted for any data element may also be defined in the CDM XML Schema. Examples of such restrictions may include a set of enumerated values (e.g., 'YES'/'NO', or 'RTN'/'TVN'), or other user-defined data type variation.

6.3.2.5 In value fields that represent a time tag which are in UTC, values shall follow the conventions of the *ndm:epochType* data type used in all CCSDS NDM/XML schemas. An example of this format:

*yyyy-mm-dd***T***hh:mm:ss*[.*d*→*d*]

where '*yyyy*' is the year, '*mm*' is the two-digit month, '*dd*' is the two-digit day-of-month separated by hyphens, '**T**' is a fixed separator between the date and time portions of the string, and '*hh:mm:ss*[*.d→d*]' is the time in hours, minutes, seconds and fractional seconds separated by colons. As many 'd' characters to the right of the period as required may be used to obtain the required precision, up to the maximum allowed for a fixed point number. Because all times in the CDM are UTC, the "Z" indicator allowed by the CCSDS Time Codes standard should be omitted. All fields require leading zeros.

6.3.2.6 In the value fields that represent TIME_LASTOB, a choice of data types is allowed that includes the exact time (See 6.3.2.5 for formatting rules) or an elapsed time, from the message creation time, of the last observation used in the OD of the object . When the elapsed time option is chosen, the notation "LT", "-", and "GT" will be used. The "LT" means "less than" as in "less than six hours". The "-" means "to" as in "6-12" means "six to twelve hours". The "GT" means "greater than" as in "greater than twelve hours".

6.3.3 CDM UNITS IN XML

6.3.3.1 Many of the CDM tags must have a units attribute. In all cases, the units shall match those specified in table 3-2 and table 3-4 (including case). Table 6-1 gives examples of XML keyword tags with specified units.

Table 6-1: Example XML Keyword Tags With Specified Units

Tag	Units	Example
MISS_DISTANCE	m	<MISS_DISTANCE units="m">715<MISS_DISTANCE>
RELATIVE_SPEED	m/s	<RELATIVE_SPEED units="m/s">14762<RELATIVE_SPEED>
ACTUAL_OD_SPAN	d	<ACTUAL_OD_SPAN units="d">5.50</ACTUAL_OD_SPAN>
MAXIMUM_OBS_GAP	h	<MAXIMUM_OBS_GAP units="h">2.3</MAXIMUM_OBS_GAP>

6.3.4 CDM COMMENTS IN XML

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

6.3.5 XML TEXT VALUES

Text values in XML instantiations (i.e., the values between the opening and closing tags), shall consist of all uppercase or all lowercase characters; an exception is made for values between the <COMMENT> and </COMMENT> tags, which may be in any case desired by the user.

ANNEX A

ABBREVIATIONS AND ACRONYMS

(INFORMATIVE)

ASCII	American Standard Code for Information Interchange
CA	Conjunction Assessment
CDM	Conjunction Data Message
CCSDS	Consultative Committee for Space Data Systems
DCA	Dynamic Calibration of the Atmosphere
EGM	Earth Gravitational Model
EME2000	Earth Mean Equator and Equinox of J2000 (Julian Date 2000)
GCRF	Geocentric Celestial Reference Frame
ICD	Interface Control Document
ITRF	International Terrestrial Reference Frame
KVN	Keyword = Value Notation
NDM	Navigation Data Message
OD	Orbit Determination
RCS	Radar Cross Section
RMS	Root Mean Square
RTN	Radial, Transverse and Normal
SANA	Space Assigned Numbers Authority
SEDR	Specific Energy Dissipation Rate
TCA	Time of Closest Approach

TVN	Transverse, Velocity and Normal
UTC	Coordinated Universal Time
WGS	World Geodetic System
XML	Extensible Markup Language

ANNEX B

RATIONALE AND REQUIREMENTS FOR

CONJUNCTION DATA MESSAGES

(INFORMATIVE)

B1 OVERVIEW

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 Member Agencies and satellite operators. There are many ways of organizing requirements, but the categorization of requirements is not as important as the agreement to a sufficiently comprehensive set. In this section the requirements are organized into three categories:

a) Primary Requirements: These are the most elementary and necessary requirements. They would exist no matter the context in which the CCSDS is operating, i.e., regardless of pre-existing conditions within the CCSDS, its Member Agencies, or other independent users.

b) Heritage Requirements: These are additional requirements that derive from pre-existing Member Agency or other independent user requirements, conditions or needs. Ultimately these carry the same weight as the Primary Requirements. This Proposed Recommended Standard reflects heritage requirements pertaining to some of the CCSDS Areas' home institutions collected during the preparation of the document; it does not speculate on heritage requirements that could arise from other sources. Corrections and/or additions to these requirements are expected during future updates.

c) Desirable Characteristics: These are not requirements, but they are felt to be important or useful features of the Proposed Recommended Standard.

B2 PRIMARY REQUIREMENTS ACCEPTED BY THE CDM

Table B-1: Primary Requirements

Reqt #	Requirement	Rationale	Trace
CDM-P01	The CDM data shall be provided in digital form (computer file).	Facilitates computerized processing of CDMs.	3.1.1, 3.1.2
CDM-P02	The CDM shall be provided in data structures (e.g., files) that are readily ported between, and useable within, 'all' computing environments in use by Member Agencies.	The CCSDS objective of promoting interoperability is not met if messages are produced using esoteric or proprietary data structures.	3.1.2
CDM-P03	The CDM shall be provided using file name syntax and length that do not violate computer constraints for those computing environments in use by Member Agencies.	The CCSDS objective of promoting interoperability is not met if messages are provided using non-standard file name syntax or length.	3.1.3
CDM-P04	The CDM shall provide a mechanism by which messages may be uniquely identified and clearly annotated. The file name alone is considered insufficient for this purpose.	Facilitates discussion between a message recipient and the originator should it become necessary.	Table 3-1
CDM-P05	The CDM shall clearly and unambiguously identify the two objects involved in a conjunction.	This information is fundamental to the operator(s) of the objects in the conjunction. Cited as required in ISO 16158 (reference [D2]).	Table 3-3
CDM-P06	The CDM shall provide the time of closest approach of the two objects involved in the conjunction.	This datum is required in order to determine remaining reaction time, to assess the risk of collision, and to assess potential preventive measures. Cited as required in ISO 16158 (reference [D2]).	Table 3-2
CDM-P07	The CDM shall provide time measurements (time stamps, or epochs) in commonly used, clearly specified systems.	The CCSDS objective of promoting interoperability is not met if time measurements are produced in esoteric or proprietary time systems.	6.2.2.11, 6.3.2.5, Table 3-2
CDM-P08	The CDM shall provide the states of the two objects involved in the conjunction at the time of closest approach.	The states at time of closest approach are required for calculation of collision probability in most methods. This information is useful to operators who wish to perform an independent assessment of the conjunction and/or the probability of collision. Cited as desirable in ISO 16158 (reference [D2]).	Table 3-4

Reqt #	Requirement	Rationale	Trace
CDM-P09	The CDM shall provide the miss distance of the two objects involved in the conjunction at the time of closest approach.	This datum is required in order to assess the risk of collision and assess potential preventive measures. Cited as required in ISO 16158 (reference [D2]).	Table 3-2
CDM-P10	The CDM shall provide state vector information for both objects involved in the conjunction 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.	3.4.1, Table 3-3,
CDM-P11	The CDM 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).	Table 3-4, 4.3.10, 6.2.3, 6.3.3
CDM-P12	The CDM shall provide a covariance matrix that includes at least 6x6 position/velocity uncertainty information.	The determination of a satellite state is subject to measurement and process uncertainties at all phases of its development. Consideration of this uncertainty is a necessary part of conjunction analysis and risk assessment. The covariance matrix captures the requisite uncertainty. Cited as required in ISO 16158 (reference [D2]).	Table 3-4
CDM-P13	The CDM shall provide the most recently known operational status of the two objects.	This datum is required in order to assess the risk of collision and assess potential preventive measures. Cited as required in ISO 16158 (reference [D2).	Table 3-3
CDM-P14	The CDM shall allow the possibility to exchange information regarding conjunctions of objects orbiting an arbitrary body or point in space.	While Earth is the most likely object about which orbiting objects may collide, there are other orbit centers with more than one orbiting object (e.g., the Moon, Mars, Earth/Sun L1, Earth/Sun L2).	Table 3-2
CDM-P15	The CDM shall provide data and/or metadata that will allow the recipient to calculate the probability of collision if it is not provided by the CDM originator.	Some CDM originators will not want to explicitly provide a probability of collision, but their customers may be interested in performing a calculation of their own based on data in the CDM.	Table 3-2, Table 3-3, Table 3-4

Reqt #	Requirement	Rationale	Trace
CDM-P16	The CDM must not require of the receiving exchange partner the separate application of, or modeling of, spacecraft dynamics or gravitational force models, or integration or propagation.	The situation in which a CDM is provided may not allow time for checking/confirming a predicted conjunction by a recipient. Some operators may not be able to perform the required computations.	Table 3-2, Table 3-3, Table 3-4

Table B-2: Heritage Requirements

ID	Requirement	Rationale	Trace
CDM-H01	The CDM shall be provided in, or shall include, an ASCII format.	ASCII character-based messages promote interoperability. ASCII messages are useful in transferring data between heterogeneous computing systems, because the ASCII character set is nearly universally used and is interpretable by all popular systems. In addition, direct human-readable dumps of text to displays, emails, documents or printers are possible without preprocessing.	2.2.1
CDM-H02	The CDM shall not require software supplied by other Agencies.	This principle was agreed early in the history of the CCSDS Navigation Working Group.	1.2.2

Table B-3: Desirable Characteristics

ID	Requirement	Rationale	Trace
CDM-D01	The CDM 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 CDM has been proven in other operations facilities.	Table 3-1
CDM-D02	The CDM 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 standards developed by a given CCSDS Working Group will be consistent.	2.2.3, 4.1

ID	Requirement	Rationale	Trace
CDM-D03	CDM originators should maintain consistency with respect to the optional keywords provided in their implementations, i.e., the composition of the CDMs provided should not change on a frequent basis.	Implementations that change on a frequent basis do not promote stable operations or interoperability.	1.2.3
CDM-D04	The CDM should allow the option for originators to provide a probability of collision of the two objects involved in the conjunction.	Some CDM originators will be interested in providing this datum. Cited as desirable by ISO 16158 (reference [D2])	Table 3-2
CDM-D05	The CDM should provide information with which each object's spherical radius may be calculated.	The object radius is required for calculation of collision probability in most methods, which usually model objects as spheres given the lack of attitude information.	Table 3-4
CDM-D06	The CDM should provide the threshold of close approach used by the originator in the screening.	This datum is desirable in order to assess the risk of collision and assess potential preventive measures. Cited as desirable by ISO 16158 (reference [D2])	Table 3-2
CDM-D07	The CDM should provide the components of the relative position at the time of closest approach.	These data allow an operator to quickly do a first order qualitative assessment of the probability of collision immediately upon receipt of a CDM.	Table 3-2
CDM-D08	The CDM should provide the relative velocity of the two objects in the conjunction at the time of closest approach.	This datum is desirable in order to assess the risk of collision and assess potential preventive measures. Called out as desirable by ISO 16158 (reference [D2])	Table 3-2

ANNEX C

CONJUNCTION INFORMATION DESCRIPTION

(INFORMATIVE)

C1 RELATIVE DATA

TCA (Time of Closest Approach). This is the date and time of the predicted conjunction. This time tag is also the epoch of the relative state vector, Object1 and Object2 state vectors, as well as the effective time of the covariance matrices for both Object1 and Object2.

COLLISION_PROBABILITY. The probability that Object1 and Object2 will collide.

COLLISION_PROBABILITY_METHOD. The method used to compute the probability of collision. Options are "FOSTER-1992" (see reference [D5]), "CHAN-1997" (see reference [D6]), "PATERA-2001" (see reference [D7]), "ALFANO-2005" (see reference [D8]), or "OTHER". If "OTHER" is specified, a full reference should be provided in CDM comments.

MISS_DISTANCE. The miss distance tells how close the two objects are going to be based upon the conjunction assessment screening results.

RELATIVE_SPEED. The relative speed defines how fast the two objects are moving relative to each other at the time of the predicted encounter.

RELATIVE_POSITION/RELATIVE_VELOCITY. Object2's position/velocity relative to Object1's position/velocity, calculated by taking the difference of the position and velocity vectors relative to the frame in which they are defined, with components expressed in the Object1-centered RTN coordinate frame at the time of closest approach.

RTN Coordinate Frame. The Object1-centered RTN coordinate frame is defined as: R (Radial) is the unit vector in the radial direction, N (Normal) is the unit vector normal to the satellite's inertial orbit plane (in the direction of the satellite's angular momentum), and T (Transverse) is the unit vector that completes the right-hand coordinate frame (see Figure C-1).

TVN Coordinate Frame. The Object1-centered TVN coordinate frame is defined as: V (Velocity) is the unit vector in the velocity direction, N (Normal) is the unit vector normal to the satellite's inertial orbit plane (in the direction of the satellite's angular momentum), and T (Transverse) is the unit vector that completes the right-hand coordinate frame (see Figure C-1).

Commonality Between RTN and TVN. The primary difference between the RTN and the TVN frames is that the RTN frame is anchored on the unit radial vector R and TVN frame is anchored on the unit velocity vector V. The unit normal vector N is the same vector for both

the RTN and TVN frames. The unit transverse vector T completes the right-hand coordinate frame for both the RTN and TVN frames, but is not in the same direction for both frames. The TVN frame can be particularly useful for analyzing elliptical orbits where the user would like one coordinate axes to align with the velocity direction of motion. The RTN and TVN frames are the same when Object1 is at apoapsis, periapsis or when its orbit is perfectly circular. Transformations from EME2000, GCRF or ITRF to RTN or TVN should always use inertial velocities in the transformation.

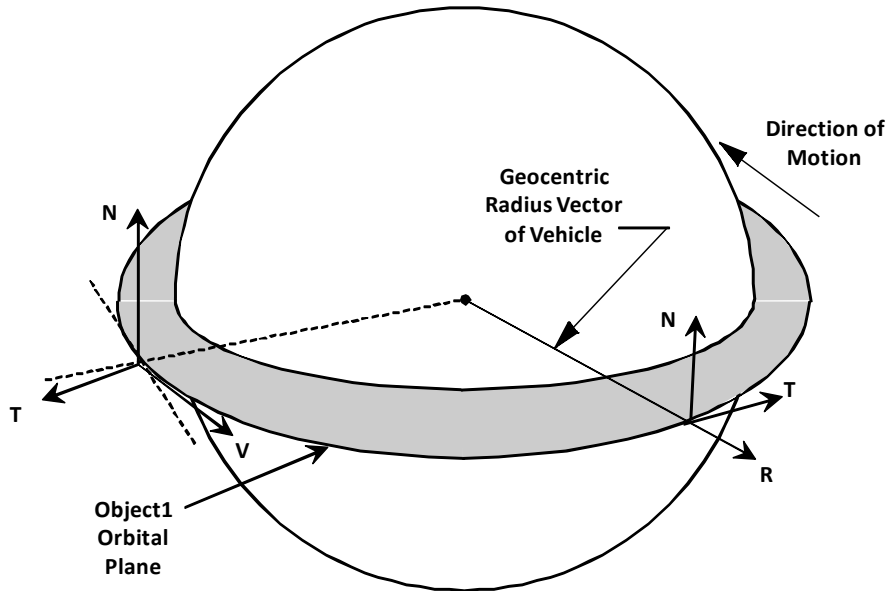

Figure C- 1: Definition of the RTN and TVN Coordinate Frames

SCREEN_VOLUME_SHAPE/SCREEN_VOLUME: The screening volume shape (ellipsoid or box), is the shape of the screening volume used to screen the satellite catalog for possible conjunctors with Object1. The screening volume is the component size of the screening volume shape (in the Object1 centered RTN or TVN reference frame).

C2 METADATA

ADDITIONAL_TRACKING. This parameter provides information concerning whether additional sensor tracking has been applied to the orbit determination of the object. Once a potential conjunction has been determined, it is common practice to then use additional sensor resources where possible, beyond what is normally used, to better define the object's orbit.

C3 ORBIT DETERMINATION PARAMETERS

Observation. Provides a unique measurement of a satellite's location from a single sensor at a single time (e.g. azimuth from a single sensor at a single time).

TIME_LASTOB. This parameter provides information about the time of the last accepted observation that was used in the creation of the object's state vector. It can be entered as an exact time or an elapsed time, from the message creation time, that includes the time of the last good observation that was used in the creation of the object's state vector. The rules for the latter case are defined below for near earth (NE) and far from earth (FE) objects (FE is defined as any object with a period greater than 225 minutes):

For all NE objects:

<6 hours from message creation time

6 to 12 hours from message creation time

>12 hours from message creation time

For all FE objects:

<24 hours from message creation time

24 to 48 hours from message creation time

>48 hours from message creation time

RECOMMENDED_OD_SPAN. Describes how many days of observations were recommended for the orbit determination (OD) of the object.

ACTUAL_OD_SPAN. Based on the observations available and the RECOMMENDED_OD_SPAN, this is the actual time span used for the OD of the object.

OBS_AVAILABLE. This parameter provides the number of observations, for the recommended time span, that were available for the OD.

OBS_USED. This parameter provides the number of observations, for the recommended time span, that were accepted for the OD.

Sensor Track. A sensor track is defined as a set of at least three observations for the same object, observed by the same sensor, where each observation is within a specified number of minutes (which is dependent on the orbit regime of the object) of the other observations in the track.

TRACKS_AVAILABLE. This parameter provides the number of sensor tracks, for the recommended time span, that were available for the OD. This provides information about the independence of the observational data used in the OD.

TRACKS_USED. This parameter provides the number of sensor tracks, for the recommended time span, that were accepted for the OD. This provides information about the independence of the observational data used in the OD.

MAXIMUM_OBS_GAP. The maximum time between observations in the OD of the object.

WEIGHTED_RMS. The weighted RMS is defined as:

$$Weighted\ RMS = \sqrt{\frac{\sum_{i=1}^{N} w_i (y_i - \hat{y}_i)^2}{N}}$$

Where

y_i is the observation measurement at the ith time

$\hat{y}_i$ is the current estimate of y_i,

$w_i = \frac{1}{\sigma_i^2}$ is the weight (sigma) associated with the measurement at the ith time

and N is the number of observations.

This is a value that can generally identify the quality of the most recent vector update, and is used by the analyst in evaluating the OD process. A value of 1.00 is ideal.

C4 MODEL PARAMETERS

GRAVITY_MODEL. Indicates the geopotential model used in the state vector update. The degree (D) and order (O) of the spherical harmonic coefficients applied should be given along with the name of the model.

ATMOSPHERIC_MODEL. Indicates the atmospheric drag model used in the state vector update.

N_BODY_PERTURBATIONS. Indicates which (if any) N-body gravitational perturbations were included in the state vector update. The value is a comma separated list of the body names.

SOLAR_RAD_PRESSURE. Indicates whether perturbations due to solar radiation pressure were included in the state vector update.

EARTH_TIDES. Indicates whether perturbations due to solid earth and ocean tides were included in the state vector update.

C5 ADDITIONAL PARAMETERS

AREA. This is the area of the object (m**2). The area could be defined by using a radar cross section (RCS).

CD_AREA_OVER_MASS. The perturbation of the object due to atmospheric drag (m**2/kg) used to propagate the state vector and covariance to TCA. Defined as $C_D \bullet A/m$, where C_D is the drag coefficient, A is the area of the object and m is the mass of the object.

CR_AREA_OVER_MASS. The perturbation of the object due to solar radiation pressure (m**2/kg) used to propagate the state vector and covariance to TCA. Defined as $C_R \bullet A/m$, where C_R is the solar radiation pressure coefficient, A is the area of the object and m is the mass of the object.

THRUST_ACCELERATION. The object's acceleration due to in-track thrust (m/s**2) used to propagate the state vector and covariance of the object to TCA.

SEDR. SEDR (Specific Energy Dissipation Rate) (W/kg) is representative of the amount of energy being removed from a satellite's orbit by atmospheric drag. It is a very useful metric for characterizing satellites since it takes into account both the drag environment (atmospheric density) and the "area to mass ratio" of the specific object. It does this by including *drag acceleration* in the computation. Drag acceleration is proportional to atmospheric density and to satellite area to mass.

SEDR is computed as follows:

Instantaneous SEDR at time t is given by

$$SEDR(t) = -\vec{A}_D \bullet \vec{V}$$

where,

$\vec{A}_D$ = drag acceleration vector (inertial)

$\vec{V}$ = velocity vector (inertial)

Average SEDR over the orbit determination interval is given by

$$\frac{1}{T}\int_0^t SEDR(t)dt$$

where,

in order to correctly average over a complete orbital revolution, T is an integer multiple of the satellite period. This consideration is primarily for eccentric orbits. Aside from this consideration, T is the orbit determination interval.

C6 COVARIANCE MATRIX

The covariance matrix is obligatory for the position and velocity terms, given in the lower triangular form of a 6x6 matrix. Optional terms for CD_AREA_OVER_MASS (denoted 'DRG'), CR_AREA_OVER_MASS (denoted 'SRP'), and THRUST_ACCELERATION (denoted 'THR') should to be added to the 6x6 matrix, in the lower triangular form, to complete a 9x9 matrix. If any element in any of these rows (7, 8,or 9) is provided, then all of the elements for that row must be provided (i.e., a subset of the terms for any of these rows is not allowed). The purpose for providing the 7, 8 and 9 terms is so that users, who have the propagator model available, can correctly propagate the 6x6 position and velocity covariance to another time point.

ANNEX D

INFORMATIVE REFERENCES

(INFORMATIVE)

[D1] *Navigation Data—Definitions and Conventions*. Report Concerning Space Data System Standards, CCSDS 500.0-G-3. Green Book. Issue 3. Washington, D.C.: CCSDS, May 2010.

[D2] "Space Systems - Avoiding Collisions Among Orbiting Objects: Best Practices, Data Requirements, and Operational Concepts", ISO AWI 16158, 5-June-2011.

[D3] Astrodynamics—Propagation Specifications, Technical Definitions, and Recommended Practices, ANSI/AIAA S-131-2010, American National Standards Institute, 25-August-2010.

[D4] Alfano, Salvatore, "Review of Conjunction Probability Methods for Short-term Encounters", Proceedings of the 2007 AAS/AIAA Space Flight Mechanics Meeting, AAS-07-148, February 2007.

[D5] Foster, J. L., and Estes, H. S., "A Parametric Analysis of Orbital Debris Collision Probability and Maneuver Rate for Space Vehicles," NASA/JSC-25898, August 1992.

[D6] Chan, K., "Collision Probability Analyses for Earth-Orbiting Satellites," Proceedings of the 7th International Space Conference of Pacific Basin Societies, Nagasaki, Japan, July 1997.

[D7] Patera, R. P. "General Method for Calculating Satellite Collision Probability," Journal of Guidance, Control, and Dynamics, Vol. 24, No. 4, July-August 2001, pp. 716-722.

[D8] Alfano, S. "A Numerical Implementation of Spherical Object Collision Probability," Journal of the Astronautical Sciences, Vol. 53, No. 1, January-March 2005, pp. 103-109.

ANNEX E

SECURITY, SANA AND PATENT CONSIDERATIONS

(INFORMATIVE)

E1 SECURITY CONSIDERATIONS

E1.1 ANALYSIS OF SECURITY CONSIDERATIONS

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

E1.2 CONSEQUENCES OF NOT APPLYING SECURITY TO THE TECHNOLOGY

The consequences of not applying security to the systems and networks on which this Proposed Standard is implemented could include potential loss, corruption, and theft of data. Because these messages are used in collision avoidance analyses and potential maneuvers, 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.

E1.3 POTENTIAL THREATS AND ATTACK SCENARIOS

Potential threats or attack scenarios include, but are not limited to, (a) unauthorized access to the programs/processes that generate and interpret the messages, and (b) unauthorized access to the messages during transmission between exchange partners. Protection from unauthorized access during transmission is especially important if the mission utilizes open ground networks such as the Internet to provide ground station connectivity for the exchange of data formatted in compliance with this Proposed Standard. It is strongly recommended that potential threats or attack scenarios applicable to the systems and networks on which this Proposed Standard is implemented be addressed by the management of those systems and networks.

E1.4 DATA PRIVACY

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

E1.5 DATA INTEGRITY

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

Standard is implemented.

E1.6 AUTHENTICATION OF COMMUNICATING ENTITIES

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

E1.7 DATA TRANSFER BETWEEN COMMUNICATING ENTITIES

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

E1.8 CONTROL OF ACCESS TO RESOURCES

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

E1.9 AUDITING OF RESOURCE USAGE

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

E1.10 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.

E1.11 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.

E2 SANA CONSIDERATIONS

The CDM XML schema and a transform to the CDM KVN version will be registered with the SANA Operator.

E3 PATENT CONSIDERATIONS

The recommendations of this document have no patent issues.

ANNEX F

CDM XML SCHEMA DEFINITION

(INFORMATIVE)

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            xmlns:ndm="urn:ccsds:recommendation:navigation:schema:ndmxml"
            targetNamespace="urn:ccsds:recommendation:navigation:schema:ndmxml"
            elementFormDefault="unqualified"
            attributeFormDefault="unqualified">

<!--================================================================-->
<!-- NOTE: This is version 1.0 of the CDM/XML Schema (10/17/2011).  -->
<!--                                                                -->
<!-- Compatible document versions are:                              -->
<!--    NDM/XML 505.0-B-1   Blue Book (12/2010)                     -->
<!--    ODM     502.0-B-2   Blue Book (11/2009)                     -->
<!--                                                                -->
<!-- ********************  BLUE BOOK CHANGE LOG  ******************** -->
<!--                                                                -->
<!--================================================================-->

<!--================================================================-->
<!-- Include common schemas                                         -->
<!--================================================================-->
<xsd:include schemaLocation="./ndmxml-1.0-navwg-common.xsd"/>
<xsd:include schemaLocation="./ndmxml-1.0-ccsds-common.xsd"/>

<!--================================================================-->
<!-- A CDM consists of a "header" and a "body".                     -->
<!--================================================================-->
  <xsd:complexType name="cdmType">
    <xsd:sequence>
      <xsd:element name="header" type="ndm:cdmHeader"/>
      <xsd:element name="body" type="ndm:cdmBody"/>
    </xsd:sequence>
    <xsd:attribute name="id" use="required" fixed="CCSDS_CDM_VERS"/>
    <xsd:attribute name="version" use="required" fixed="1.0"/>
  </xsd:complexType>

<!--================================================================-->
<!-- A CDM header.                                                  -->
<!--================================================================-->
  <xsd:complexType name="cdmHeader">
    <xsd:sequence>
      <xsd:element name="COMMENT" type="xsd:string" minOccurs="0"
maxOccurs="unbounded"/>
      <xsd:element name="CREATION_DATE" type="ndm:epochType"/>
      <xsd:element name="ORIGINATOR" type="xsd:string"/>
      <xsd:element name="CDM_FOR" type="xsd:string" minOccurs="0"/>
      <xsd:element name="MESSAGE_ID" type="xsd:string"/>
```

```
    </xsd:sequence>
  </xsd:complexType>

<!--=================================================================-->
<!-- The CDM "body" consists of relative metadata/data and           -->
<!-- two segments, described below.                                  -->
<!--=================================================================-->
  <xsd:complexType name="cdmBody">
    <xsd:sequence>
      <xsd:element name="relativeMetadataData" type="ndm:relativeMetadataData"/>
      <xsd:element name="segment" type="ndm:cdmSegment" minOccurs="2"
maxOccurs="2" />
    </xsd:sequence>
  </xsd:complexType>

<!--=================================================================-->
<!-- The CDM relative metadata and data section.                     -->
<!--=================================================================-->
  <xsd:complexType name="relativeMetadataData">
    <xsd:sequence>
      <xsd:element name="COMMENT" type="xsd:string" minOccurs="0"
maxOccurs="unbounded"/>
      <xsd:element name="TCA" type="ndm:epochType"/>
      <xsd:element name="MISS_DISTANCE" type="ndm:lengthType" minOccurs="0"/>
      <xsd:element name="RELATIVE_SPEED" type="ndm:dvType" minOccurs="0"/>
      <xsd:element name="relativeStateVector" type="ndm:relativeStateVectorType"
/>
      <xsd:element name="ORBIT_CENTER" type="xsd:string" minOccurs="0" />
            <xsd:element name="START_SCREEN_PERIOD" type="ndm:epochType"
minOccurs="0"/>
      <xsd:element name="STOP_SCREEN_PERIOD" type="ndm:epochType"
minOccurs="0"/>
      <xsd:element name="SCREEN_VOLUME_FRAME" type="ndm:screenFrameType"
minOccurs="0"/>
      <xsd:element name="SCREEN_VOLUME_SHAPE" type="ndm:volumeShapeType"
minOccurs="0"/>
      <xsd:element name="SCREEN_VOLUME_X" type="ndm:lengthType" minOccurs="0"/>
      <xsd:element name="SCREEN_VOLUME_Y" type="ndm:lengthType" minOccurs="0"/>
      <xsd:element name="SCREEN_VOLUME_Z" type="ndm:lengthType" minOccurs="0"/>
      <xsd:element name="ENTRY_TIME" type="ndm:epochType" minOccurs="0"/>
      <xsd:element name="EXIT_TIME" type="ndm:epochType" minOccurs="0"/>
      <xsd:element name="COLLISION_PROBABILITY" type="ndm:nonNegativeDouble"
minOccurs="0"/>
      <xsd:element name="COLLISION_PROBABILITY_METHOD" type="xsd:string"
minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>

<!--=================================================================-->
<!-- The CDM "segment" consists of a "metadata" section and a "data"    -->
<!-- section.                                                        -->
<!--=================================================================-->
  <xsd:complexType name="cdmSegment">
    <xsd:sequence>
      <xsd:element name="metadata" type="ndm:cdmMetadata"/>
      <xsd:element name="data" type="ndm:cdmData"/>
    </xsd:sequence>
```

```
  </xsd:complexType>

<!--=================================================================-->
<!-- CDM metadata section.                                           -->
<!--=================================================================-->
  <xsd:complexType name="cdmMetadata">
    <xsd:sequence>
      <xsd:element name="COMMENT" type="xsd:string" minOccurs="0"
maxOccurs="unbounded"/>
      <xsd:element name="OBJECT" type="ndm:objectType" />
      <xsd:element name="OBJECT_NUMBER" type="xsd:positiveInteger" />
      <xsd:element name="SAT_CATALOG" type="xsd:string" />
      <xsd:element name="OBJECT_NAME" type="xsd:string" />
      <xsd:element name="OBJECT_ID" type="xsd:string"/>
      <xsd:element name="OBJECT_TYPE" type="ndm:objectDescriptionType "
minOccurs="0" />
      <xsd:element name="OPERATOR_CONTACT_POSITION" type="xsd:string"
minOccurs="0" />
      <xsd:element name="OPERATOR_ORGANIZATION" type="xsd:string" minOccurs="0"
/>
      <xsd:element name="OPERATOR_PHONE" type="xsd:string" minOccurs="0" />
      <xsd:element name="OPERATOR_EMAIL" type="xsd:string" minOccurs="0" />
      <xsd:element name="EPHEMERIS_NAME" type="xsd:string" />
      <xsd:element name="NUMBER_SENSORS" type="xsd:positiveInteger"
minOccurs="0" />
      <xsd:element name="TRACKING_DATA_TYPES" type="xsd:string" minOccurs="0" />
      <xsd:element name="ADDITIONAL_TRACKING" type="ndm:yesNoType" minOccurs="0"
/>
      <xsd:element name="COVARIANCE_METHOD" type="ndm:covarianceMethodType" />
      <xsd:element name="MANEUVERABLE" type="ndm:maneuverableType" />
      <xsd:element name="MAN_INCLUDED" type="ndm:yesNoType" minOccurs="0" />
      <xsd:element name="REF_FRAME" type="ndm:referenceFrameType" />

      <xsd:element name="GRAVITY_MODEL" type="xsd:string" minOccurs="0" />
      <xsd:element name="ATMOSPHERIC_MODEL" type="xsd:string" minOccurs="0" />
      <xsd:element name="N_BODY_PERTURBATIONS" type="xsd:string" minOccurs="0"
/>
      <xsd:element name="SOLAR_RAD_PRESSURE" type="ndm:yesNoType" minOccurs="0"
/>
      <xsd:element name="EARTH_TIDES" type="ndm:yesNoType" minOccurs="0" />
      <xsd:element name="INTRACK_THRUST" type="ndm:yesNoType" minOccurs="0" />
    </xsd:sequence>
  </xsd:complexType>

<!--=================================================================-->
<!-- CDM data section.                                               -->
<!--=================================================================-->
  <xsd:complexType name="cdmData">
    <xsd:sequence>
      <xsd:element name="COMMENT" type="xsd:string" minOccurs="0"
maxOccurs="unbounded"/>
      <xsd:element name="odParameters" type="ndm:odParametersType"
minOccurs="0"/>
      <xsd:element name="additionalParameters"
type="ndm:additionalParametersType" minOccurs="0"/>
      <xsd:element name="stateVector" type="ndm:cdmStateVectorType"/>
      <xsd:element name="covarianceMatrix" type="ndm:cdmCovarianceType"/>
```

```
    </xsd:sequence>
  </xsd:complexType>

<!--=================================================================-->
<!-- Other complex types unique to the CDM.                          -->
<!--=================================================================-->
  <xsd:complexType name="odParametersType">
    <xsd:sequence>
      <xsd:element name="COMMENT" type="xsd:string" minOccurs="0"
maxOccurs="unbounded"/>
      <xsd:element name="TIME_LASTOB" type="ndm:timeObType" minOccurs="0"/>
      <xsd:element name="RECOMMENDED_OD_SPAN" type="ndm:dayIntervalType"
minOccurs="0"/>
      <xsd:element name="ACTUAL_OD_SPAN" type="ndm:dayIntervalType"
minOccurs="0"/>
      <xsd:element name="MAXIMUM_OBS_GAP" type="ndm:hourIntervalType"
minOccurs="0"/>
      <xsd:element name="OBS_AVAILABLE" type="xsd:positiveInteger"
minOccurs="0"/>
      <xsd:element name="OBS_USED" type="xsd:positiveInteger" minOccurs="0"/>
      <xsd:element name="TRACKS_AVAILABLE" type="xsd:positiveInteger"
minOccurs="0"/>
      <xsd:element name="TRACKS_USED" type="xsd:positiveInteger" minOccurs="0"/>
      <xsd:element name="WEIGHTED_RMS" type="ndm:nonNegativeDouble"
minOccurs="0"/>
      <xsd:element name="TIME_NEXT_UPDATE" type="ndm:hourIntervalType"
minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="additionalParametersType">
    <xsd:sequence>
      <xsd:element name="COMMENT" type="xsd:string" minOccurs="0"
maxOccurs="unbounded"/>
      <xsd:element name="AREA " type="ndm:areaType" minOccurs="0"/>
      <xsd:element name="MASS" type="ndm:massType" minOccurs="0"/>
      <xsd:element name="CD_AREA_OVER_MASS" type="ndm:m2kgType" minOccurs="0"/>
      <xsd:element name="CR_AREA_OVER_MASS" type="ndm:m2kgType" minOccurs="0"/>
      <xsd:element name="THRUST_ACCELERATION" type="ndm:ms2Type" minOccurs="0"/>
      <xsd:element name="SEDR" type="ndm:wkgType" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="relativeStateVectorType">
    <xsd:sequence>
      <xsd:element name="RELATIVE_POSITION_R" type="ndm:lengthType"
minOccurs="0"/>
      <xsd:element name="RELATIVE_POSITION_T" type="ndm:lengthType"
minOccurs="0"/>
      <xsd:element name="RELATIVE_POSITION_N" type="ndm:lengthType"
minOccurs="0"/>
      <xsd:element name="RELATIVE_VELOCITY_R" type="ndm:dvType" minOccurs="0"/>
      <xsd:element name="RELATIVE_VELOCITY_T" type="ndm:dvType" minOccurs="0"/>
      <xsd:element name="RELATIVE_VELOCITY_N" type="ndm:dvType" minOccurs="0"/>
  </xsd:sequence>
  </xsd:complexType>
```

```
  <xsd:complexType name="cdmStateVectorType">
    <xsd:sequence>
      <xsd:element name="COMMENT" type="xsd:string" minOccurs="0"
maxOccurs="unbounded"/>
      <xsd:element name="X" type="ndm:positionType"/>
      <xsd:element name="Y" type="ndm:positionType"/>
      <xsd:element name="Z" type="ndm:positionType"/>
      <xsd:element name="X_DOT" type="ndm:velocityType"/>
      <xsd:element name="Y_DOT" type="ndm:velocityType"/>
      <xsd:element name="Z_DOT" type="ndm:velocityType"/>
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="cdmCovarianceType">
    <xsd:sequence>
      <xsd:element name="COMMENT" type="xsd:string" minOccurs="0"
maxOccurs="unbounded"/>
      <xsd:element name="CR_R" type="ndm:areaUnits"/>
      <xsd:element name="CT_R" type="ndm:areaUnits"/>
      <xsd:element name="CT_T" type="ndm:areaUnits"/>
      <xsd:element name="CN_R" type="ndm:areaUnits"/>
      <xsd:element name="CN_T" type="ndm:areaUnits"/>
      <xsd:element name="CN_N" type="ndm:areaUnits"/>
      <xsd:element name="CRDOT_R" type="ndm:m2sType"/>
      <xsd:element name="CRDOT_T" type="ndm:m2sType"/>
      <xsd:element name="CRDOT_N" type="ndm:m2sType"/>
      <xsd:element name="CRDOT_RDOT" type="ndm:m2s2Type"/>
      <xsd:element name="CTDOT_R" type="ndm:m2sType"/>
      <xsd:element name="CTDOT_T" type="ndm:m2sType"/>
      <xsd:element name="CTDOT_N" type="ndm:m2sType"/>
      <xsd:element name="CTDOT_RDOT" type="ndm:m2s2Type"/>
      <xsd:element name="CTDOT_TDOT" type="ndm:m2s2Type"/>
      <xsd:element name="CNDOT_R" type="ndm:m2sType"/>
      <xsd:element name="CNDOT_T" type="ndm:m2sType"/>
      <xsd:element name="CNDOT_N" type="ndm:m2sType"/>
      <xsd:element name="CNDOT_RDOT" type="ndm:m2s2Type"/>
      <xsd:element name="CNDOT_TDOT" type="ndm:m2s2Type"/>
      <xsd:element name="CNDOT_NDOT" type="ndm:m2s2Type"/>
      <xsd:element name="CDRG_R" type="ndm:m3kgType" minOccurs="0"/>
      <xsd:element name="CDRG_T" type="ndm:m3kgType" minOccurs="0"/>
      <xsd:element name="CDRG_N" type="ndm:m3kgType" minOccurs="0"/>
      <xsd:element name="CDRG_RDOT" type="ndm:m3kgsType" minOccurs="0"/>
      <xsd:element name="CDRG_TDOT" type="ndm:m3kgsType" minOccurs="0"/>
      <xsd:element name="CDRG_NDOT" type="ndm:m3kgsType" minOccurs="0"/>
      <xsd:element name="CDRG_DRG" type="ndm:m4kg2Type" minOccurs="0"/>
      <xsd:element name="CSRP_R" type="ndm:m3kgType" minOccurs="0"/>
      <xsd:element name="CSRP_T" type="ndm:m3kgType" minOccurs="0"/>
      <xsd:element name="CSRP_N" type="ndm:m3kgType" minOccurs="0"/>
      <xsd:element name="CSRP_RDOT" type="ndm:m3kgsType" minOccurs="0"/>
      <xsd:element name="CSRP_TDOT" type="ndm:m3kgsType" minOccurs="0"/>
      <xsd:element name="CSRP_NDOT" type="ndm:m3kgsType" minOccurs="0"/>
      <xsd:element name="CSRP_DRG" type="ndm:m4kg2Type" minOccurs="0"/>
      <xsd:element name="CSRP_SRP" type="ndm:m4kg2Type" minOccurs="0"/>
      <xsd:element name="CTHR_R" type="ndm:m2s2Type" minOccurs="0"/>
      <xsd:element name="CTHR_T" type="ndm:m2s2Type" minOccurs="0"/>
      <xsd:element name="CTHR_N" type="ndm:m2s2Type" minOccurs="0"/>
      <xsd:element name="CTHR_RDOT" type="ndm:m2s3Type" minOccurs="0"/>
```

```
      <xsd:element name="CTHR_TDOT" type="ndm:m2s3Type" minOccurs="0"/>
      <xsd:element name="CTHR_NDOT" type="ndm:m2s3Type" minOccurs="0"/>
      <xsd:element name="CTHR_DRG" type="ndm:m3kgs2Type" minOccurs="0"/>
      <xsd:element name="CTHR_SRP" type="ndm:m3kgs2Type" minOccurs="0"/>
      <xsd:element name="CTHR_THR" type="ndm:m2s4Type" minOccurs="0"/>
    </xsd:sequence>
  </xsd:complexType>

  <xsd:complexType name="timeObType">
    <xsd:choice>
      <xsd:element name="lastObAt" type="ndm:epochType"/>
      <xsd:element name="timeSince" type="ndm:timeBucketHourType"/>
    </xsd:choice>
  </xsd:complexType>

  <xsd:complexType name="timeBucketHourType">
    <xsd:simpleContent>
      <xsd:extension base="ndm:timeBucketType">
        <xsd:attribute ref="ndm:cdmUnits" fixed="h"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="lengthType">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="dvType">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m/s"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="hourIntervalType">
    <xsd:simpleContent>
      <xsd:extension base="ndm:positiveDouble">
        <xsd:attribute ref="ndm:cdmUnits" fixed="h"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="dayIntervalType">
    <xsd:simpleContent>
      <xsd:extension base="ndm:positiveDouble">
        <xsd:attribute ref="ndm:cdmUnits" fixed="d"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>


<!--================================================================-->
```

```
<!-- Simple types unique to the CDM.                                        -->
<!--************************************************************************-->
  <xsd:simpleType name="objectType">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="OBJECT1"/>
      <xsd:enumeration value="OBJECT2"/>
    </xsd:restriction>

  </xsd:simpleType>  <xsd:simpleType name="screenFrameType">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="RTN"/>
      <xsd:enumeration value="TVN"/>
    </xsd:restriction>
  </xsd:simpleType>

  <xsd:simpleType name="volumeShapeType">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="ELLIPSOID"/>
      <xsd:enumeration value="BOX"/>
    </xsd:restriction>
  </xsd:simpleType>

  <xsd:simpleType name="referenceFrameType">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="EME2000"/>
      <xsd:enumeration value="GCRF"/>
      <xsd:enumeration value="ITRF"/>
    </xsd:restriction>
  </xsd:simpleType>

  <xsd:simpleType name="covarianceMethodType">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="CALCULATED"/>
      <xsd:enumeration value="DEFAULT"/>
    </xsd:restriction>
  </xsd:simpleType>

  <xsd:simpleType name="objectDescriptionType">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="PAYLOAD"/>
      <xsd:enumeration value="ROCKET BODY"/>
      <xsd:enumeration value="DEBRIS"/>
      <xsd:enumeration value="UNKNOWN"/>
      <xsd:enumeration value="OTHER"/>
    </xsd:restriction>
  </xsd:simpleType>

  <xsd:simpleType name="maneuverableType">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="YES"/>
      <xsd:enumeration value="NO"/>
      <xsd:enumeration value="UNKNOWN"/>
    </xsd:restriction>
  </xsd:simpleType>

  <xsd:simpleType name="timeBucketType">
    <xsd:restriction base="xsd:string">
```

```
      <xsd:enumeration value="LT 6"/>
      <xsd:enumeration value="6-12"/>
      <xsd:enumeration value="GT 12"/>
      <xsd:enumeration value="LT 24"/>
      <xsd:enumeration value="24-48"/>
      <xsd:enumeration value="GT 48"/>
    </xsd:restriction>
  </xsd:simpleType>

  <xsd:complexType name="m2sType">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m**2/s"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="m2s2Type">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m**2/s**2"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="m2s3Type">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m**2/s**3"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="m2s4Type">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m**2/s**4"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="m2kgType">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m**2/kg"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

<xsd:complexType name="m3kgType">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m**3/kg"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
```

```
  <xsd:complexType name="m3kgsType">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m**3/kg*s"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="m3kgs2Type">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m**3/kg*s**2"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="m4kg2Type">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m**2/kg**2"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="ms2Type">
    <xsd:simpleContent>
      <xsd:extension base="xsd:double">
        <xsd:attribute ref="ndm:cdmUnits" fixed="m/s**2"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

  <xsd:complexType name="wkgType">
    <xsd:simpleContent>
      <xsd:extension base="ndm:nonNegativeDouble">
        <xsd:attribute ref="ndm:cdmUnits" fixed="W/kg"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

<!--================================================================-->
<!-- Attributes unique to the CDM.                                  -->
<!--================================================================-->
  <xsd:attribute name="cdmUnits">
    <xsd:simpleType>
      <xsd:restriction base="xsd:string">
        <xsd:enumeration value="h"/>
        <xsd:enumeration value="d"/>
        <xsd:enumeration value="m"/>
        <xsd:enumeration value="m**2/s"/>
        <xsd:enumeration value="m**2/s**2"/>
        <xsd:enumeration value="m/s"/>
        <xsd:enumeration value="m/s**2"/>
        <xsd:enumeration value="m**2/s**3"/>
        <xsd:enumeration value="m**2/s**4"/>
        <xsd:enumeration value="m**2/kg"/>
        <xsd:enumeration value="m**3/kg"/>
```

```
        <xsd:enumeration value="m**3/kg*s"/>
        <xsd:enumeration value="m**3/kg*s**2"/>
        <xsd:enumeration value="m**2/kg**2"/>
        <xsd:enumeration value="W/kg"/>
      </xsd:restriction>
    </xsd:simpleType>
  </xsd:attribute>
</xsd:schema>
```

Figure F- 1: An Example of a CDM XML Schema

ANNEX G

CDM XML TO KVN TRANSLATOR - XLST IMPLEMENTATION

(INFORMATIVE)

```
<?xml version="1.0" encoding="utf-8"?>
<xsl:stylesheet version="2.0"
                xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
                xmlns:msxsl="urn:schemas-microsoft-com:xslt"
                exclude-result-prefixes="msxsl"

xmlns:ndm="urn:ccsds:recommendation:navigation:schema:ndmxml"
>
  <xsl:output method="text" indent="yes"/>

  <xsl:strip-space elements="*"/>
  <xsl:preserve-space elements="ndm:cdm ndm:segment"/>

  <xsl:template match="ndm:cdm[@id]">
    <xsl:value-of select="@id"/>         = <xsl:value-of
select="@version"/>
    <xsl:apply-templates />
  </xsl:template>

  <xsl:template match="ndm:header/ndm:COMMENT">
    COMMENT <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:header/ndm:CREATION_DATE">
    CREATION_DATE                        = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:header/ndm:ORIGINATOR">
    ORIGINATOR                           = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:header/ndm:CDM_FOR">
    CDM_FOR                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:header/ndm:MESSAGE_ID">
    MESSAGE_ID                           = <xsl:value-of select="."/>
  </xsl:template>

  <xsl:template match="ndm:relativeMetadataData/ndm:COMMENT">
    COMMENT <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:TCA">
    TCA                                  = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:MISS_DISTANCE">
    MISS_DISTANCE                        = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:RELATIVE_SPEED">
    RELATIVE_SPEED                       = <xsl:value-of select="."/>
  </xsl:template>
```

```
  <xsl:template
match="ndm:relativeMetadataData/ndm:relativeStateVector/ndm:RELATIVE_POSIT
ION_R">
    RELATIVE_POSITION_R                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:relativeMetadataData/ndm:relativeStateVector/ndm:RELATIVE_POSIT
ION_T">
    RELATIVE_POSITION_T                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:relativeMetadataData/ndm:relativeStateVector/ndm:RELATIVE_POSIT
ION_N">
    RELATIVE_POSITION_N                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:relativeMetadataData/ndm:relativeStateVector/ndm:RELATIVE_VELOC
ITY_R">
    RELATIVE_VELOCITY_R                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:relativeMetadataData/ndm:relativeStateVector/ndm:RELATIVE_VELOC
ITY_T">
    RELATIVE_VELOCITY_T                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:relativeMetadataData/ndm:relativeStateVector/ndm:RELATIVE_VELOC
ITY_N">
    RELATIVE_VELOCITY_N                 = <xsl:value-of select="."/>
  </xsl:template>

  <xsl:template match="ndm:relativeMetadataData/ndm:ORBIT_CENTER">
    ORBIT_CENTER                        = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:START_SCREEN_PERIOD">
    START_SCREEN_PERIOD                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:STOP_SCREEN_PERIOD">
    STOP_SCREEN_PERIOD                  = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:SCREEN_VOLUME_FRAME">
    SCREEN_VOLUME_FRAME                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:SCREEN_VOLUME_SHAPE">
    SCREEN_VOLUME_SHAPE                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:SCREEN_VOLUME_X">
    SCREEN_VOLUME_X                     = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:SCREEN_VOLUME_Y">
    SCREEN_VOLUME_Y                     = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:SCREEN_VOLUME_Z">
    SCREEN_VOLUME_Z                     = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:ENTRY_TIME">
    ENTRY_TIME                          = <xsl:value-of select="."/>
```

```
  </xsl:template>
  <xsl:template match="ndm:relativeMetadataData/ndm:EXIT_TIME">
    EXIT_TIME                       = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:relativeMetadataData/ndm:COLLISION_PROBABILITY">
    COLLISION_PROBABILITY           = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:relativeMetadataData/ndm:COLLISION_PROBABILITY_METHOD">
    COLLISION_PROBABILITY_METHOD    = <xsl:value-of select="."/>
  </xsl:template>

  <xsl:template match="ndm:segment/ndm:metadata/ndm:COMMENT">
    COMMENT <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:OBJECT">
    OBJECT                          = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:OBJECT_NUMBER">
    OBJECT_NUMBER                   = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:SAT_CATALOG">
    SAT_CATALOG                     = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:OBJECT_NAME">
    OBJECT_NAME                     = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:OBJECT_ID">
    OBJECT_ID                       = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:OBJECT_TYPE">
    OBJECT_TYPE                     = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:metadata/ndm:OPERATOR_CONTACT_POSITION">
    OPERATOR_CONTACT_POSITION       = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:metadata/ndm:OPERATOR_ORGANIZATION">
    OPERATOR_ORGANIZATION           = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:OPERATOR_PHONE">
    OPERATOR_PHONE                  = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:OPERATOR_EMAIL">
    OPERATOR_EMAIL                  = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:EPHEMERIS_NAME">
    EPHEMERIS_NAME                  = <xsl:value-of select="."/>
  </xsl:template>

  <xsl:template match="ndm:segment/ndm:metadata/ndm:NUMBER_SENSORS">
    NUMBER_SENSORS                  = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:TRACKING_DATA_TYPES">
    TRACKING_DATA_TYPES             = <xsl:value-of select="."/>
```

```
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:ADDITIONAL_TRACKING">
    ADDITIONAL_TRACKING                  = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:COVARIANCE_METHOD">
    COVARIANCE_METHOD                    = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:MANEUVERABLE">
    MANEUVERABLE                         = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:MAN_INCLUDED">
    MAN_INCLUDED                         = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:REF_FRAME">
    REF_FRAME                            = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:GRAVITY_MODEL">
    GRAVITY_MODEL                        = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:ATMOSPHERIC_MODEL">
    ATMOSPHERIC_MODEL                    = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:N_BODY_PERTUBATIONS">
    N_BODY_PERTUBATIONS                  = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:SOLAR_RAD_PRESSURE">
    SOLAR_RAD_PRESSURE                   = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:EARTH_TIDES">
    EARTH_TIDES                          = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:metadata/ndm:INTRACK_THRUST">
    INTRACK_THRUST                       = <xsl:value-of select="."/>
  </xsl:template>

  <xsl:template match="ndm:segment/ndm:data/ndm:COMMENT">
    COMMENT <xsl:value-of select="."/>
  </xsl:template>

  <xsl:template match="ndm:segment/ndm:data/ndm:odParameters/ndm:COMMENT">
    COMMENT <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:TIME_LASTOB">
    TIME_LASTOB                          = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:RECOMMENDED_OD_SPAN">
    RECOMMENDED_OD_SPAN                  = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:ACTUAL_OD_SPAN">
    ACTUAL_OD_SPAN                       = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:MAXIMUM_OBS_GAP">
    MAXIMUM_OBS_GAP                      = <xsl:value-of select="."/>
```

```
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:OBS_AVAILABLE">
    OBS_AVAILABLE                    = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:OBS_USED">
    OBS_USED                         = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:TRACKS_AVAILABLE">
    TRACKS_AVAILABLE                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:TRACKS_USED">
    TRACKS_USED                      = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:WEIGHTED_RMS">
    WEIGHTED_RMS                     = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:odParameters/ndm:TIME_NEXT_UPDATE">
    TIME_NEXT_UPDATE                 = <xsl:value-of select="."/>
  </xsl:template>

  <xsl:template
match="ndm:segment/ndm:data/ndm:additionalParameters/ndm:COMMENT">
    COMMENT <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:additionalParameters/ndm:AREA">
    AREA                             = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:additionalParameters/ndm:MASS">
    MASS                             = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:additionalParameters/ndm:CD_AREA_OVER_MASS
">
    CD_AREA_OVER_MASS                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:additionalParameters/ndm:CR_AREA_OVER_MASS
">
    CR_AREA_OVER_MASS                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:additionalParameters/ndm:THRUST_ACCELERATI
ON">
    THRUST_ACCELERATION              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:additionalParameters/ndm:SEDR">
    SEDR                             = <xsl:value-of select="."/>
  </xsl:template>
```

```
  <xsl:template match="ndm:segment/ndm:data/ndm:stateVector/ndm:COMMENT">
    COMMENT <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:data/ndm:stateVector/ndm:X">
    X                                   = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:data/ndm:stateVector/ndm:Y">
    Y                                   = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:data/ndm:stateVector/ndm:Z">
    Z                                   = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:data/ndm:stateVector/ndm:X_DOT">
    X_DOT                               = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:data/ndm:stateVector/ndm:Y_DOT">
    Y_DOT                               = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template match="ndm:segment/ndm:data/ndm:stateVector/ndm:Z_DOT">
    Z_DOT                               = <xsl:value-of select="."/>
  </xsl:template>

  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:COMMENT">
    COMMENT <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CR_R">
    CR_R                                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CT_R">
    CT_R                                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CT_T">
    CT_T                                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CN_R">
    CN_R                                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CN_T">
    CN_T                                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CN_N">
    CN_N                                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CRDOT_R">
    CRDOT_R                             = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CRDOT_T">
```

```
    CRDOT_T                                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CRDOT_N">
    CRDOT_N                                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CRDOT_RDOT">
    CRDOT_RDOT                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTDOT_R">
    CTDOT_R                                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTDOT_T">
    CTDOT_T                                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTDOT_N">
    CTDOT_N                                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTDOT_RDOT">
    CTDOT_RDOT                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTDOT_TDOT">
    CTDOT_TDOT                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CNDOT_R">
    CNDOT_R                                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CNDOT_T">
    CNDOT_T                                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CNDOT_N">
    CNDOT_N                                 = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CNDOT_RDOT">
    CNDOT_RDOT                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CNDOT_TDOT">
    CNDOT_TDOT                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CNDOT_NDOT">
    CNDOT_NDOT                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CDRG_R">
    CDRG_R                                  = <xsl:value-of select="."/>
```

```
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CDRG_T">
    CDRG_T                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CDRG_N">
    CDRG_N                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CDRG_RDOT">
    CDRG_RDOT                           = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CDRG_TDOT">
    CDRG_TDOT                           = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CDRG_NDOT">
    CDRG_NDOT                           = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CDRG_DRG">
    CDRG_DRG                            = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CSRP_R">
    CSRP_R                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CSRP_T">
    CSRP_T                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CSRP_N">
    CSRP_N                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CSRP_RDOT">
    CSRP_RDOT                           = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CSRP_TDOT">
    CSRP_TDOT                           = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CSRP_NDOT">
    CSRP_NDOT                           = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CSRP_DRG">
    CSRP_DRG                            = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CSRP_SRP">
    CSRP_SRP                            = <xsl:value-of select="."/>
  </xsl:template>
```

```
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTHR_R">
    CTHR_R                                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTHR_T">
    CTHR_T                                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTHR_N">
    CTHR_N                                = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTHR_RDOT">
    CTHR_RDOT                             = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTHR_TDOT">
    CTHR_TDOT                             = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTHR_NDOT">
    CTHR_NDOT                             = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTHR_DRG">
    CTHR_DRG                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTHR_SRP">
    CTHR_SRP                              = <xsl:value-of select="."/>
  </xsl:template>
  <xsl:template
match="ndm:segment/ndm:data/ndm:covarianceMatrix/ndm:CTHR_THR">
    CTHR_THR                              = <xsl:value-of select="."/>
  </xsl:template>

</xsl:stylesheet>
```

Figure G- 1: An XLST Implementation to Translate a CDM From XML to KVN