The Consultative Committee for Space Data Systems

Recommendation for Space Data System Standards

CONJUNCTION DATA MESSAGE

RECOMMENDED STANDARD

CCSDS 508.0-B-1

Note:
This current issue includes all updates through Technical Corrigendum 2, dated October 2021

BLUE BOOK

June 2013

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FOREWORD

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

This Recommended 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 conjunction assessment originator 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 Recommended Standard and can incorporate features not addressed by this Recommended Standard.

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– Swedish Space Corporation (SSC)/Sweden.
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DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 508.0-B-1	Conjunction Data Message, Recommended Standard, Issue 1	June 2013	Current issue
CCSDS 508.0-B-1 EC 1	Editorial change 1	March 2014	– Corrects broken hyperlinks; – updates references to superseded documents; – updates obsolete style elements.
CCSDS 508.0-B-1 EC 2	Editorial change 2	February 2018	Addresses minor typographical and layout issues.
CCSDS 508.0-B-1 Cor. 1	Technical Corrigendum 1	June 2018	Adds direction to use Space Assigned Numbers Authority (SANA) registry values.
CCSDS 508.0-B-1 Cor. 2	Technical Corrigendum 2	October 2021	Adds specifications and examples for messages with elements qualified with respect to a namespace.

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

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

This Recommended Standard will:

a) facilitate interoperability and enable consistent warning between data originators who supply CA and the satellite owner/operators who use it;

b) facilitate automation for the CA processes; and

c) provide critical information to enable timely CA decisions.

This document includes requirements and criteria that the message format has been designed to meet (see annex D). Also included are informative descriptions of conjunction information pertinent to performing CA (see annex E).

1.2 APPLICABILITY

This Recommended Standard is applicable to satellite operations in all environments in which close approaches and collisions among satellites are concerns. It contains the specification for a CDM designed for applications involving conjunction information interchange between originators of CAs 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 and annex E.

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 because of the large amount of data typically present. 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.

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.

This Recommended 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.

The methods used to predict conjunctions and calculate the probability of collision, and the definition of the conjunction assessment accuracy underlying a particular CDM, are also outside the scope of this Recommended Standard (the interested reader can consult references in annex F).

1.3 DOCUMENT STRUCTURE

Section 2 provides a brief overview of the CCSDS-recommended 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 contains an Implementation Conformance Statement (ICS) proforma that may be used by implementers to compactly describe their implementations.

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

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

Annex D provides rationale and requirements for the CDM Recommended Standard.

Annex E provides a description of the CA information contained in the CDM.

Annex F provides informative references.

1.4 CONVENTIONS AND DEFINITIONS

1.4.1 NOTATION

1.4.1.1 Unit Notations

The following conventions for unit notations apply throughout this Recommended Standard. Insofar as possible, an effort has been made to use units that are part of the International System of Units (SI); 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]). The units used within this document are as follows:

– km: kilometers;

– m: meters;

– d: days, 86400 SI seconds;

– s: SI seconds;

– kg: kilograms;

– W: watts;

– %: percent.

1.4.1.2 General

The following notational conventions are used in this document:

a) multiplication of units is denoted with a single asterisk '*' (e.g., 'kg*s');

b) exponents of units are denoted with a double asterisk '**' (e.g., m^2 = m**2);

c) division of units is denoted with a single forward slash '/' (e.g., m/s).

1.4.2 NOMENCLATURE

1.4.2.1 General

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

1.4.2.2 Normative Text

The following conventions apply for the normative specifications in this Recommended Standard:

a) the words 'shall' and 'must' imply a binding and verifiable specification;

b) the word 'should' implies an optional, but desirable, specification;

c) the word 'may' implies an optional specification;

d) the words 'is', 'are', and 'will' imply statements of fact.

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

1.4.2.3 Informative Text

In the normative sections of this document (sections 3-6), informative text is set off from the normative specifications either in notes or under one of the following subsection headings:

– Overview;

– Discussion.

1.4.3 OTHER CONVENTIONS

1.4.3.1 Terminology

In this document, the term 'ASCII' is used generically to refer to the text character set defined in reference [2]. The terms 'N/A' and 'n/a' are defined to mean 'not available' or 'not applicable'.

1.4.3.2 Orthography

The following terms define orthographic conventions for XML notation in this Recommended 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.

1.5 REFERENCES

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

[1] *The International System of Units (SI)*. 8th ed. Sèvres, France: BIPM, 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.

[4] Paul V. Biron and Ashok Malhotra, eds. *XML Schema Part 2: Datatypes*. 2nd ed. W3C Recommendation. N.p.: W3C, October 2004.

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

Cor. 2

[6] *XML Specification for Navigation Data Messages*. Issue 2. Recommendation for Space Data System Standards (Blue Book), CCSDS 505.0-B-2. Washington, D.C.: CCSDS, May 2021.

2 OVERVIEW

2.1 GENERAL

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

2.2 CDM BASIC CONTENT

The CDM is ASCII format encoded either in plain text or XML (see references [2], [3], and [4]). This CDM document describes a KVN-formatted message as well as an XML-formatted message (it is desirable that an ICD specify which of these formats will be exchanged).

The CDM contains information about a single conjunction between Object1 and Object2. It contains

– Object1/Object2 positions/velocities at TCA with respect to one of a small set of widely used reference frames (ITRF, GCRF—see reference [F11], EME2000);

– Object1/Object2 covariances at TCA with respect to an object centered reference frame;

– the relative position/velocity of Object2 with respect to an Object1 centered reference frame;

– information relevant to how all the above data was determined.

This information is used by satellite owner/operators to evaluate the risk of a conjunction and plan maneuvers if warranted by that agency/organization. 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, INTERNATIONAL_DESIGNATOR, 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).

NOTES

1 KVN messages contain one keyword per line (see 6.3.1.4).

2 The order of keywords in the KVN representation is fixed by this Recommended Standard (see 6.3.1.9).

3.1.2 The CDM shall be plain text consisting of CA data for a single conjunction event. It shall be easily readable by both humans and computers.

3.1.3 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

The CDM header shall consist of the KVN elements defined in table 3-1, which 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 6.3.4 for formatting rules.)	COMMENT This is a comment	No
CREATION_DATE	Message creation date/time in Coordinated Universal Time (UTC). (See 6.3.2.6 for formatting rules.)	2010-03-12T22:31:12.000 2010-071T22:31:12.000	Yes
ORIGINATOR	Creating agency or owner/operator. Value should be the ‘Abbreviation’ value from the SANA ‘Organizations’ registry (https://sanaregistry.org/r/organizations) for an organization that has the Role of ‘Conjunction Data Message Originator’. (See 5.2.9 for formatting rules.)	JSPOC, ESA SST, CAESAR, JPL, SDC	Yes
MESSAGE_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. (See 5.2.9 for formatting rules.)	201113719185 ABC-12_34	Yes

Cor. 1

3.3 CDM RELATIVE METADATA/DATA

The CDM relative metadata/data shall consist of the KVN elements defined in table 3-2, which 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 if applicable; and

d) whether the item is obligatory or optional.

Table 3-2: CDM KVN Relative Metadata/Data

Keyword	Description	Units	Obligatory
COMMENT	(See 6.3.4 for formatting rules.)	n/a	No
TCA	The date and time in UTC of the closest approach. (See 6.3.2.6 for formatting rules.)	n/a	Yes
MISS_DISTANCE	The norm of the relative position vector. It indicates how close the two objects are at TCA. Data type = double.	m	Yes

Keyword	Description	Units	Obligatory
RELATIVE_SPEED	The norm of the relative velocity vector. It indicates how fast the two objects are moving relative to each other at TCA. Data type = double.	m/s	No
RELATIVE_POSITION_R	The R component of Object2's position relative to Object1's position in the Radial, Transverse, and Normal (RTN) coordinate frame. (See annex E for definition.) Data type = double.	m	No
RELATIVE_POSITION_T	The T component of Object2's position relative to Object1's position in the RTN coordinate frame. (See annex E for definition.) Data type = double.	m	No
RELATIVE_POSITION_N	The N component of Object2's position relative to Object1's position in the RTN coordinate frame. (See annex E for definition.) Data type = double.	m	No
RELATIVE_VELOCITY_R	The R component of Object2's velocity relative to Object1's velocity in the RTN coordinate frame. (See annex E for definition.) Data type = double.	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 E for definition.) Data type = double.	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 E for definition.) Data type = double.	m/s	No
START_SCREEN_PERIOD	The start time in UTC of the screening period for the conjunction assessment. (See 6.3.2.6 for formatting rules.)	n/a	No
STOP_SCREEN_PERIOD	The stop time in UTC of the screening period for the conjunction assessment. (See 6.3.2.6 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 Transverse, Velocity, and Normal (TVN). (See annex E for definition.)	n/a	No
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. Data type = double.	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. Data type = double.	m	No

Keyword	Description	Units	Obligatory
SCREEN_VOLUME_Z	The N component size of the screening volume in the SCREEN_VOLUME_FRAME. Data type = double.	m	No
SCREEN_ENTRY_TIME	The time in UTC when Object2 enters the screening volume. (See 6.3.2.6 for formatting rules.)	n/a	No
SCREEN_EXIT_TIME	The time in UTC when Object2 exits the screening volume. (See 6.3.2.6 for formatting rules.)	n/a	No
COLLISION_PROBABILITY	The probability (denoted 'p' where 0.0<=p<=1.0), that Object1 and Object2 will collide. Data type = double.	n/a	No
COLLISION_PROBABILITY_METHOD	The method that was used to calculate the collision probability. (See annex E for definition.)	n/a	No

3.4 CDM METADATA

The CDM metadata shall consist of the KVN elements defined in table 3-3, which specifies for each KVN metadata item:

a) the keyword to be used;

b) a short description of the item;

c) normative values or examples of allowed values;

d) whether the 'Normative Values/Examples' column contains normative values (N) or examples of allowed values (E) for the item; and

e) whether the item is obligatory or optional.

NOTE – 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 6.3.4 for formatting rules.)	COMMENT This is a comment	E	No
OBJECT	The object to which the metadata and data apply (Object1 or Object2).	OBJECT1 OBJECT2	N	Yes
OBJECT_DESIGNATOR	The satellite catalog designator for the object. (See 5.2.9 for formatting rules.)	12345	E	Yes

Cor. 1

Keyword	Description	Normative Values/ Examples	N/E	Obligatory
CATALOG_NAME	The satellite catalog used for the object. Value should be taken from the SANA 'Conjunction Data Message CATALOG_NAME' registry (https://sanaregistry.org/r/cdm_catalog). (See 5.2.9 for formatting rules.)	SATCAT	E	Yes
OBJECT_NAME	Spacecraft name for the object.	SPOT, ENVISAT, IRIDIUM, INTELSAT	E	Yes
INTERNATIONAL_DESIGNATOR	The full international designator for the object. Values shall 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. (See 5.2.9 for further formatting rules.)	2002-021A 2002-009A 1997-020AA 1998-037ABC 2001-049PE UNKNOWN	E	Yes
OBJECT_TYPE	The object type.	PAYLOAD ROCKET BODY DEBRIS UNKNOWN OTHER	N	No
OPERATOR_CONTACT_POSITION	Contact position of the owner/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 or organization for the object.	+49615130312	E	No
OPERATOR_EMAIL	Email address of the contact position or organization of the object.	JOHN.DOE@ SOMEWHERE.NET	E	No

Keyword	Description	Normative Values/ Examples	N/E	Obligatory
EPHEMERIS_NAME	Unique name of the external ephemeris file used for the object or NONE. This is used to indicate whether an external (i.e., Owner/Operator [O/O] provided) ephemeris file was used to calculate the CA. If 'NONE' is specified, then the output of the most current Orbit Determination (OD) of the CDM originator was used in the CA.	EPHEMERIS SATELLITE A, NONE	E	Yes
COVARIANCE_METHOD	Method used to calculate the covariance during the OD that produced the state vector, or whether an arbitrary, non-calculated default value was used. Caution should be used when using the default value for calculating collision probability.	CALCULATED DEFAULT	N	Yes
MANEUVERABLE	The maneuver capacity of the object. (See 1.4.3.1 for definition of 'N/A'.)	YES NO N/A	N	Yes
ORBIT_CENTER	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 [F1]) and be the same for both Object1 and Object2.	GCRF (see reference [F11]) EME2000 ITRF	N	Yes
GRAVITY_MODEL	The gravity model used for the OD of the object. (See annex E under GRAVITY_MODEL for definition).	EGM-96: 36D 36O WGS-84_GEOID: 24D 24O JGM-2 : 41D 41O	E	No
ATMOSPHERIC_MODEL	The atmospheric density model used for the OD of the object. If 'NONE' is specified, then no atmospheric model was used.	JACCHIA 70 MSIS JACCHIA 70 DCA NONE	E	No

Keyword	Description	Normative Values/ Examples	N/E	Obligatory
N_BODY_PERTURBATIONS	The N-body gravitational perturbations used for the OD of the object. If 'NONE' is specified, then no third-body gravitational perturbations were used.	MOON, SUN JUPITER NONE	E	No
SOLAR_RAD_PRESSURE	Indication of whether solar radiation pressure perturbations were used for the OD of the object.	YES NO	N	No
EARTH_TIDES	Indication of whether solid Earth and ocean tides were used for the OD of the object.	YES NO	N	No
INTRACK_THRUST	Indication of whether in-track thrust modeling was used for the OD of the object.	YES NO	N	No

3.5 CDM DATA

3.5.1 The CDM Data section shall be formed as logical blocks:

– OD Parameters;

– Additional Parameters;

– State Vector; and

– Covariance Matrix.

3.5.2 The logical blocks of the CDM Data section shall consist of KVN elements as defined in table 3-4, which specifies for each data item:

a) the keyword to be used;

b) a short description of the item;

c) the units to be used if applicable; and

d) whether the item is obligatory or optional.

Table 3-4: CDM KVN Data

Keyword	Description	Units	Obligatory
COMMENT	(See 6.3.4 for formatting rules.)	n/a	No
OD Parameters			
COMMENT	(See 6.3.4 for formatting rules.)	n/a	No
TIME_LASTOB_START	The start of a time interval (UTC) that contains the time of the last accepted observation. (See 6.3.2.6 for formatting rules.) For an exact time, the time interval is of zero duration (i.e., same value as that of TIME_LASTOB_END).	n/a	No
TIME_LASTOB_END	The end of a time interval (UTC) that contains the time of the last accepted observation. (See 6.3.2.6 for formatting rules.) For an exact time, the time interval is of zero duration (i.e., same value as that of TIME_LASTOB_START).	n/a	No
RECOMMENDED_OD_SPAN	The recommended OD time span calculated for the object. (See annex E for definition.) Data type = double.	d	No
ACTUAL_OD_SPAN	Based on the observations available and the RECOMMENDED_OD_SPAN, the actual time span used for the OD of the object. (See annex E for definition.) Data type = double.	d	No
OBS_AVAILABLE	The number of observations available for the OD of the object. (See annex E for definition.) Data type = integer.	n/a	No
OBS_USED	The number of observations accepted for the OD of the object. (See annex E for definition.) Data type = integer.	n/a	No
TRACKS_AVAILABLE	The number of sensor tracks available for the OD of the object. (See annex E for definition.) Data type = integer.	n/a	No
TRACKS_USED	The number of sensor tracks accepted for the OD of the object. (See annex E for definition.) Data type = integer.	n/a	No
RESIDUALS_ACCEPTED	The percentage of residuals accepted in the OD of the object. Data type = double, range = 0.0 to 100.0.	%	No
WEIGHTED_RMS	The weighted Root Mean Square (RMS) of the residuals from a batch least squares OD. (See annex E for definition.) Data type = double.	n/a	No

Keyword	Description	Units	Obligatory
Additional Parameters			
COMMENT	(See 6.3.4 for formatting rules.)	n/a	No
AREA_PC	The actual area of the object. (See annex E for definition.) Data type = double.	m**2	No
AREA_DRG	The effective area of the object exposed to atmospheric drag. (See annex E for definition.) Data type = double.	m**2	No
AREA_SRP	The effective area of the object exposed to solar radiation pressure. (See annex E for definition.) Data type = double.	m**2	No
MASS	The mass of the object. Data type = double.	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 E for definition.) Data type = double.	m**2/kg	No
CR_AREA_OVER_MASS	The object's C_r •*A/m* used to propagate the state vector and covariance to TCA. (See annex E for definition.) Data type = double.	m**2/kg	No
THRUST_ACCELERATION	The object's acceleration due to in-track thrust used to propagate the state vector and covariance to TCA. (See annex E for definition.) Data type = double.	m/s**2	No
SEDR	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 E for definition.) Data type = double.	W/kg	No
State Vector (all values have data type=double)			
COMMENT	(See 6.3.4 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 E for definition) (Covariance Matrix 9×9 Lower Triangular Form. All parameters of the 6×6 position/velocity submatrix must be given. All data type=double.)			
COMMENT	(See 6.3.4 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

Keyword	Description	Units	Obligatory
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
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 DISCUSSION—CDM/KVN EXAMPLES

3.6.1 OVERVIEW

Subsections 3.6.2 through 3.6.4 show examples of a CDM message in KVN. Subsection 3.6.2 includes only obligatory keywords and subsections 3.6.3 through 3.6.4 include optional keywords as well as obligatory.

3.6.2 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
MESSAGE_ID                        = 201113719185
TCA                               = 2010-03-13T22:37:52.618
MISS_DISTANCE                     = 715                          [m]
OBJECT                            = OBJECT1
OBJECT_DESIGNATOR                 = 12345
CATALOG_NAME                      = SATCAT
OBJECT_NAME                       = SATELLITE A
INTERNATIONAL_DESIGNATOR          = 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_DESIGNATOR	= 30337	
CATALOG_NAME	= SATCAT	
OBJECT_NAME	= FENGYUN 1C DEB	
INTERNATIONAL_DESIGNATOR	= 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]

3.6.3 AN EXAMPLE OF A CDM IN KVN WHICH INCLUDES OPTIONAL KEYWORDS

CCSDS_CDM_VERS	= 1.0	
CREATION_DATE	= 2010-03-12T22:31:12.000	
ORIGINATOR	= JSPOC	
MESSAGE_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]
SCREEN_ENTRY_TIME                    = 2010-03-13T22:37:52.222
SCREEN_EXIT_TIME                     = 2010-03-13T22:37:52.824
COLLISION_PROBABILITY                = 4.835E-05
COLLISION_PROBABILITY_METHOD         = FOSTER-1992
COMMENT  Object1 Metadata
OBJECT                               = OBJECT1
OBJECT_DESIGNATOR                    = 12345
CATALOG_NAME                         = SATCAT
OBJECT_NAME                          = SATELLITE A
INTERNATIONAL_DESIGNATOR             = 1997-030E
OBJECT_TYPE                          = PAYLOAD
OPERATOR_CONTACT_POSITION            = OSA
OPERATOR_ORGANIZATION                = EUMETSAT
OPERATOR_PHONE                       = +49615130312
OPERATOR_EMAIL                       = JOHN.DOE@SOMEWHERE.NET

EPHEMERIS_NAME                       = EPHEMERIS SATELLITE A
COVARIANCE_METHOD                    = CALCULATED
MANEUVERABLE                         = 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_START                    = 2010-03-12T02:14:12.746
TIME_LASTOB_END                      = 2010-03-12T02:14:12.746
RECOMMENDED_OD_SPAN                  = 7.88                           [d]
ACTUAL_OD_SPAN                       = 5.50                           [d]
OBS_AVAILABLE                        = 592
OBS_USED                             = 579
TRACKS_AVAILABLE                     = 123
TRACKS USED                          = 119
RESIDUALS_ACCEPTED                   = 97.8                           [%]
WEIGHTED_RMS                         = 0.864
```

```
COMMENT  Object1 Additional Parameters
COMMENT  Apogee Altitude=779 km
COMMENT  Perigee Altitude=765 km
COMMENT  Inclination=86.4 deg
AREA_PC                     = 5.2                [m**2]
MASS                        = 251.6              [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]
CDRG_R                      = -1.862E+00         [m**3/kg]
CDRG_T                      = 3.530E+00          [m**3/kg]
CDRG_N                      = -3.100E-01         [m**3/kg]
CDRG_RDOT                   = -1.214E-04         [m**3/(kg*s)]
CDRG_TDOT                   = 2.580E-04          [m**3/(kg*s)]
CDRG_NDOT                   = -6.467E-05         [m**3/(kg*s)]
CDRG_DRG                    = 3.483E-06          [m**4/kg**2]
CSRP_R                      = -1.492E+02         [m**3/kg]
CSRP_T                      = 2.044E+02          [m**3/kg]
CSRP_N                      = -2.331E+01         [m**3/kg]
CSRP_RDOT                   = -1.254E-03         [m**3/(kg*s)]
CSRP_TDOT                   = 2.013E-02          [m**3/(kg*s)]
CSRP_NDOT                   = -4.700E-03         [m**3/(kg*s)]
CSRP_DRG                    = 2.210E-04          [m**4/kg**2]
```

CSRP_SRP	= 1.593E-02	[m**4/kg**2]
COMMENT Object2 Metadata		
OBJECT	= OBJECT2	
OBJECT_DESIGNATOR	= 30337	
CATALOG_NAME	= SATCAT	
OBJECT_NAME	= FENGYUN 1C DEB	
INTERNATIONAL_DESIGNATOR	= 1999-025AA	
OBJECT_TYPE	= DEBRIS	
EPHEMERIS_NAME	= NONE	
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_START	= 2010-03-12T01:14:12.746	
TIME_LASTOB_END	= 2010-03-12T03:14:12.746	
RECOMMENDED_OD_SPAN	= 2.63	[d]
ACTUAL_OD_SPAN	= 2.63	[d]
OBS_AVAILABLE	= 59	
OBS_USED	= 58	
TRACKS_AVAILABLE	= 15	
TRACKS_USED	= 15	
RESIDUALS_ACCEPTED	= 97.8	[%]
WEIGHTED_RMS	= 0.864	
COMMENT Object2 Additional Parameters		
COMMENT Apogee Altitude=786 km		
COMMENT Perigee Altitude=414 km		
COMMENT Inclination=98.9 deg		
AREA_PC	= 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]
CDRG_R	= -5.117E-01	[m**3/kg]
CDRG_T	= 1.319E+00	[m**3/kg]
CDRG_N	= -9.034E-02	[m**3/kg]
CDRG_RDOT	= -7.708E-05	[m**3/(kg*s)]
CDRG_TDOT	= 7.402E-05	[m**3/(kg*s)]
CDRG_NDOT	= -1.903E-05	[m**3/(kg*s)]
CDRG_DRG	= 1.053E-06	[m**4/kg**2]
CSRP_R	= -3.297E+01	[m**3/kg]
CSRP_T	= 8.164E+01	[m**3/kg]
CSRP_N	= -5.651E+00	[m**3/kg]
CSRP_RDOT	= -4.636E-03	[m**3/(kg*s)]
CSRP_TDOT	= 4.738E-03	[m**3/(kg*s)]
CSRP_NDOT	= -1.198E-03	[m**3/(kg*s)]
CSRP_DRG	= 6.407E-05	[m**4/kg**2]
CSRP_SRP	= 4.108E-03	[m**4/kg**2]

3.6.4 ANOTHER EXAMPLE OF A CDM IN KVN WHICH INCLUDES OPTIONAL KEYWORDS

CCSDS_CDM_VERS	= 1.0	
CREATION_DATE	= 2012-09-12T22:31:12.000	
ORIGINATOR	= SDC	
MESSAGE_FOR	= GALAXY 15	
MESSAGE_ID	= 20120912223112	
COMMENT Relative Metadata/Data		
TCA	= 2012-09-13T22:37:52.618	
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	= 2012-09-15T18:29:32:212	
SCREEN_VOLUME_FRAME	= RTN	

```
SCREEN_VOLUME_SHAPE                = ELLIPSOID
SCREEN_VOLUME_X                    = 500                              [m]
SCREEN_VOLUME_Y                    = 500                              [m]
SCREEN_VOLUME_Z                    = 500                              [m]
SCREEN_ENTRY_TIME                  = 2012-09-13T20:25:43.222
SCREEN_EXIT_TIME                   = 2012-09-13T23:44:29.324
COLLISION_PROBABILITY              = 2.355e-03
COLLISION_PROBABILITY_METHOD       = ALFANO-2005
COMMENT  Object1 Metadata
OBJECT                             = OBJECT1
OBJECT_DESIGNATOR                  = 28884
CATALOG_NAME                       = SATCAT
OBJECT_NAME                        = GALAXY 15
INTERNATIONAL_DESIGNATOR           = 2005-041A
OBJECT_TYPE                        = PAYLOAD
OPERATOR_ORGANIZATION              = INTELSAT
EPHEMERIS_NAME                     = GALAXY-15A-2012JAN-WMANEUVER23A
COVARIANCE_METHOD                  = CALCULATED
MANEUVERABLE                       = YES
REF_FRAME                          = EME2000
COMMENT Object1 Data
COMMENT Object1 OD Parameters
TIME_LASTOB_START                  = 2012-09-06T20:25:43.222
TIME_LASTOB_END                    = 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                        [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_DESIGNATOR	= 21139	
CATALOG_NAME	= SATCAT	
OBJECT_NAME	= ASTRA 1B	
INTERNATIONAL_DESIGNATOR	= 1991-051A	
OBJECT_TYPE	= PAYLOAD	
EPHEMERIS_NAME	= NONE	
COVARIANCE_METHOD	= CALCULATED	
MANEUVERABLE	= YES	
REF_FRAME	= EME2000	
COMMENT Object2 Data		
COMMENT Object2 OD Parameters		
TIME_LASTOB_START	= 2012-08-03T10:22:14.548	
TIME_LASTOB_END	= 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]

4 CDM CONTENT/STRUCTURE IN XML

4.1 DISCUSSION—THE CDM/XML SCHEMA

The CDM/XML schema is available on the SANA Web site. SANA is the registrar 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 is:

Cor. 2

– https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-2.0.0-cdm-1.0.xsd for messages with elements not qualified with respect to a namespace;

– https://sanaregistry.org/r/ndmxml_qualified/ndmxml-2.0.0-cdm-1.0.xsd for messages with elements qualified with respect to a namespace.

NOTE – Reference [6] subsection 4.3 has more information regarding messages with elements qualified with respect to a namespace.

Where possible this schema uses simple types and complex types used by the constituent schemas that make up NDMs (see reference [6]).

An Extensible Stylesheet Language Transformations (XSLT) converter is available on the SANA Web site to transform an XML CDM to a KVN CDM if desired by the CDM recipient. The location of the CDM/XML XSLT converter is:

Cor. 2

– https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-2.0.0-cdm-1.1.xsl for messages with elements not qualified with respect to a namespace;

– https://sanaregistry.org/r/ndmxml_qualified/ndmxml-2.0.0-cdm-1.1.xsl for messages with elements qualified with respect to a namespace.

NOTE – Reference [6] subsection 4.3 has more information regarding messages with elements qualified with respect to a namespace.

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 one relative metadata/data and 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 XML tags shall be uppercase and correspond with the KVN keywords in 3.2 through 3.5 (uppercase with '_' [the underscore character] as separators). The XML logical tags related to message structure shall be in lowerCamelCase.

4.3 CONSTRUCTING A CDM/XML INSTANCE

4.3.1 OVERVIEW

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

Cor. 2

4.3.3.3 For messages with elements qualified with respect to a namespace, the NDM/XML namespace must next be coded, exactly as shown:

```
xmlns:ndm="urn:ccsds:schema:ndmxml"
```

The value that follows the '`xmlns:`' in the NDM/XML name space ('`ndm`' in this case) is a prefix that must be used on every XML tag.

NOTE – This `xmlns:ndm` setting is only necessary for messages with elements qualified with respect to a namespace, but it does not hurt anything for it to appear on any NDM/XML instantiation.

4.3.3.4 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:

Cor. 2

– xsi:noNamespaceSchemaLocation="https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-2.0.0-master-2.0.xsd" for messages with elements not qualified with respect to a namespace;

– xsi:noNamespaceSchemaLocation="https://sanaregistry.org/r/ndmxml_qualified/ndmxml-2.0.0-master-2.0.xsd" for messages with elements qualified with respect to a namespace.

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

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

4.3.3.6 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.

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

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

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

NOTES

1 The following example root element tag for a CDM instantiation combines all the directions in the preceding several subsections for messages with elements **not** qualified with respect to a namespace:

```
<?xml version="1.0" encoding="UTF-8"?>
<cdm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation=
"https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-2.0.0-master-2.0.xsd"
id="CCSDS_CDM_VERS" version="1.0">
```

2 The following example root element tag for a CDM instantiation combines all the directions in the preceding several subsections for messages with elements qualified with respect to a namespace:

```
<?xml version="1.0" encoding="UTF-8"?>
<cdm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:ndm="urn:ccsds:schema:ndmxml"
xsi:noNamespaceSchemaLocation=
"https://sanaregistry.org/r/ndmxml_qualified/ndmxml-2.0.0-master-2.0.xsd"
id="CCSDS_CDM_VERS" version="1.0">
```

Cor. 2

4.3.4 THE CDM/XML HEADER SECTION

4.3.4.1 The CDM header shall have 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) optional <MESSAGE_FOR>;

d) <MESSAGE_ID>.

NOTE – The rules for these keywords are specified in 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>
  <MESSAGE_FOR>SATELLITE A</MESSAGE_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, there must appear one <relativeMetadataData></relativeMetadataData> tag pair.

4.3.5.3 Following the <relativeMetadataData></relativeMetadataData> tag pair, there must appear two <segment></segment> 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

4.3.6.1 The relative metadata/data section shall be set off by the <relativeMetadataData></relativeMetadataData> tag combination.

4.3.6.2 Immediately following the <relativeMetadataData> tag, the message may have any number of <COMMENT></COMMENT> tag pairs.

4.3.6.3 Between the <relativeMetadataData> and </relativeMetadataData> tags, the keywords shall be those 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 Immediately following the <metadata> tag, the message may have any number of <COMMENT></COMMENT> tag pairs.

4.3.7.4 Between the <metadata> and </metadata> tags for both Object1 and Object2, the keywords shall be those specified in table 3-3. The value of the keyword OBJECT shall 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 Immediately following the <data> tag, the message may have any number of <COMMENT></COMMENT> tag pairs.

4.3.8.4 Between the <data> and </data> tags, the keywords shall be those specified in table 3-4. The value of the keyword OBJECT, referenced in table 3-3, shall 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 shall be separated into constructs described in 3.5 as 'logical blocks'. Special tags in the CDM shall be used to encapsulate the information in the logical blocks of the CDM. Immediately following the special tags for logical blocks, the message may have any number of <COMMENT></COMMENT> tag pairs.

4.3.9.2 The special tags indicating logical block divisions shall be those defined in table 4-1.

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>

4.3.9.3 Another special tag that shall be used is defined in table 4-2.

Table 4-2: Another Special CDM/XML Tag

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.

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 described in 3.3 and 3.5. XML attributes shall be used to explicitly define the units or other important information associated with the given data element (see 6.4.3 for examples).

4.4 DISCUSSION—CDM/XML EXAMPLE

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

Cor. 2


```xml
<?xml version="1.0" encoding="UTF-8"?>
<cdm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:ndm="urn:ccsds:schema:ndmxml"
xsi:noNamespaceSchemaLocation="https://sanaregistry.org/r/ndmxml_unqualified/ndmxml-2.0.0-master-2.0.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>
  <MESSAGE_FOR>SATELLITE A</MESSAGE_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>
   <SCREEN_ENTRY_TIME>2010-03-13T20:25:43.222</SCREEN_ENTRY_TIME>
   <SCREEN_EXIT_TIME>2010-03-13T23:44:29.324</SCREEN_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_DESIGNATOR>12345</OBJECT_DESIGNATOR>
    <CATALOG_NAME>SATCAT</CATALOG_NAME>
    <OBJECT_NAME>SATELLITE A</OBJECT_NAME>
    <INTERNATIONAL_DESIGNATOR>1997-030E</INTERNATIONAL_DESIGNATOR>
    <OBJECT_TYPE>PAYLOAD</OBJECT_TYPE>
    <OPERATOR_CONTACT_POSITION>OSA</OPERATOR_CONTACT_POSITION>
    <OPERATOR_ORGANIZATION>EUMETSAT</OPERATOR_ORGANIZATION>
    <OPERATOR_PHONE>+49615130312</OPERATOR_PHONE>
    <OPERATOR_EMAIL>JOHN.DOE@SOMEWHERE>NET</OPERATOR_EMAIL>
   <EPHEMERIS_NAME>EPHEMERIS SATELLITE A</EPHEMERIS_NAME>
   <COVARIANCE_METHOD>CALCULATED</COVARIANCE_METHOD>
    <MANEUVERABLE>YES</MANEUVERABLE>
    <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_START>2010-03-12T02:14:12.746</TIME_LASTOB_START>
      <TIME_LASTOB_END>2010-03-12T02:14:12.746</TIME_LASTOB_END>
      <RECOMMENDED_OD_SPAN units="d">7.88</RECOMMENDED_OD_SPAN>
      <ACTUAL_OD_SPAN units="d">5.50</ACTUAL_OD_SPAN>
      <OBS_AVAILABLE>592</OBS_AVAILABLE>
      <OBS_USED>59</OBS_USED>
      <TRACKS_AVAILABLE>123</TRACKS_AVAILABLE>
      <TRACKS_USED>119</TRACKS_USED>
      <RESIDUALS_ACCEPTED units="%" >97.8</RESIDUALS_ACCEPTED>
      <WEIGHTED_RMS>0.864</WEIGHTED_RMS>
    </odParameters>
    <additionalParameters>
      <COMMENT>Object 1 Additional Parameters</COMMENT>
      <AREA_PC units="m**2">5.2</AREA_PC>
      <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>
```

```xml
      <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_DESIGNATOR>30337</OBJECT_DESIGNATOR>
    <CATALOG_NAME>SATCAT</CATALOG_NAME>
    <OBJECT_NAME>FENGYUN 1C DEB</OBJECT_NAME>
    <INTERNATIONAL_DESIGNATOR>1999-025AA</INTERNATIONAL_DESIGNATOR>
    <OBJECT_TYPE>DEBRIS</OBJECT_TYPE>
    <EPHEMERIS_NAME>NONE</EPHEMERIS_NAME>
    <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_PERTURBATIONS>MOON,SUN</N_BODY_PERTURBATIONS>
    <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_START>2010-03-12T01:14:12.746</TIME_LASTOB_START>
      <TIME_LASTOB_END>2010-03-12T03:14:12.746</TIME_LASTOB_END>
      <RECOMMENDED_OD_SPAN units="d">2.63</RECOMMENDED_OD_SPAN>
      <ACTUAL_OD_SPAN units="d">2.63</ACTUAL_OD_SPAN>
      <OBS_AVAILABLE>59</OBS_AVAILABLE>
      <OBS_USED>58</OBS_USED>
```

```xml
        <TRACKS_AVAILABLE>15</TRACKS_AVAILABLE>
        <TRACKS_USED>15</TRACKS_USED>
        <RESIDUALS_ACCEPTED units="%" >97.8</RESIDUALS_ACCEPTED>
        <WEIGHTED_RMS>0.864</WEIGHTED_RMS>
      </odParameters>
      <additionalParameters>
        <COMMENT>Object2 Additional Parameters</COMMENT>
        <COMMENT>Apogee Altitude=768 km</COMMENT>
        <COMMENT>Perigee Altitude=414 km</COMMENT>
        <COMMENT>Inclination=98.8 deg</COMMENT>
        <AREA_PC units="m**2">0.9</AREA_PC>
        <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>
```

5 CDM DATA IN GENERAL

5.1 OVERVIEW

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

5.2 RULES THAT APPLY IN KVN AND XML

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

5.2.2 The objects' state vectors and covariance shall be given 'at the time of closest approach', i.e., at the time specified in the TCA keyword.

5.2.3 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 with values between the <COMMENT> and </COMMENT> tags for the XML implementation.

5.2.4 For C_D•*A/m*, CD_AREA_OVER_MASS, a value of zero shall indicate no atmospheric drag was taken into account in the orbit determination process.

5.2.5 For C_R•*A/m*, CR_AREA_OVER_MASS, a value of zero shall indicate no solar radiation pressure was taken into account in the orbit determination process.

5.2.6 For acceleration due to in-track thrust, THRUST_ACCELERATION, a value of zero shall indicate no in-track thrust acceleration was taken into account in the orbit determination process.

5.2.7 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 6.3.2.3.

5.2.8 The covariance matrix shall be provided for the position and velocity terms, given in the lower triangular form of a 6×6 matrix. If any of the diagonal terms are zero, the entire row and column of the matrix related to that term should be discounted. Optional terms for CD_AREA_OVER_MASS (denoted 'DRG'), CR_AREA_OVER_MASS (denoted 'SRP'), and THRUST_ACCELERATION (denoted 'THR') may be added to the 6×6 matrix, in the lower triangular form, to complete a 9×9 matrix. If any element in any of these rows (7, 8, or 9) is provided, then all of the elements for that row and all preceding rows shall be provided (i.e., a subset of the terms for any of these rows is not allowed). (See annex E for definition.)

5.2.9 In the value fields for the keywords ORIGINATOR, MESSAGE_ID, OBJECT_DESIGNATOR, CATALOG_NAME and INTERNATIONAL_DESIGNATOR, values shall be given as alphanumeric text. The underscore '_' and dash '-' may also be used.

6 CDM SYNTAX

6.1 OVERVIEW

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

6.2 COMMON CDM SYNTAX

6.2.1 OVERVIEW

This subsection details the syntax requirements that are common to both KVN and XML formats.

6.2.2 COMMON CDM LINES

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

6.2.2.2 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.

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

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

6.2.3 COMMON CDM VALUES

6.2.3.1 A nonempty, valid value must be specified for each obligatory keyword.

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

6.2.3.3 Text value fields must be constructed using only all uppercase. An exception is made for comment values (see 6.2.5 for formatting rules).

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

6.2.4 COMMON CDM UNITS

6.2.4.1 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 each table (including case). (See 1.4.1.1 and 1.4.1.2 for units conventions and operations.)

6.2.4.2 The notation '[n/a]' shall not appear in a CDM as a units designator.

NOTE – Some of the items in the applicable tables are dimensionless. For such items, the table shows a unit value of 'n/a', which in this case means that there is no applicable units designator for those items (e.g., for COLLISION_PROBABILITY, WEIGHTED_RMS).

6.2.5 COMMON CDM COMMENTS

6.2.5.1 For the CDM, comment lines shall be optional.

6.2.5.2 Placement of comments shall be as specified in the tables in section 3 that describe the CDM keywords. In places where comments are permitted any number of comments may appear.

6.2.5.3 Comment text may be in any case desired by the user.

6.3 THE CDM IN KVN

6.3.1 CDM LINES IN KVN

6.3.1.1 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.

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

6.3.1.3 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.

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

6.3.1.5 Keywords must be uppercase and must not contain blanks.

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

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

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

6.3.1.9 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.

6.3.2 CDM VALUES IN KVN

6.3.2.1 Integer values shall consist of a sequence of decimal digits with an optional leading sign ('+' or '-'). If the sign is omitted, '+' shall be assumed. Leading zeroes may be used. The range of values that may be expressed as an integer is:

$$-2{,}147{,}483{,}648 \leq x \leq +2{,}147{,}483{,}647 \text{ (i.e., } -2^{31} \leq x \leq 2^{31}-1\text{).}$$

NOTE – The commas in the range of values above are thousands separators and are used only for readability.

6.3.2.2 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.

6.3.2.3 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.

6.3.2.4 Blanks shall not be used within numeric values.

6.3.2.5 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.

6.3.2.6 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*][Z]

or

*yyyy-ddd***T***hh:mm:ss*[.*d*→*d*][Z]

where '*yyyy*' is the year, '*mm*' is the two-digit month, '*dd*' is the two-digit day of the 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 Code Formats Recommended Standard should be omitted. All fields require leading zeros. (See reference [5], ASCII Time Code A or B.)

6.3.3 CDM UNITS IN KVN

When units are displayed, then:

a) there must be at least one blank character between the value and the units;

b) the units must be enclosed within square brackets (e.g., '[km]').

6.3.4 CDM COMMENTS IN KVN

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.

6.4 THE CDM IN XML

6.4.1 CDM LINES IN XML

6.4.1.1 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 line; or

– a blank line.

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

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

6.4.2 CDM VALUES IN XML

6.4.2.1 Integer values shall follow the conventions of the *integer* data type per reference [4]. Additional restrictions on the values permitted for any integer data element may also be defined in the CDM XML Schema.

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

6.4.2.2 Non-integer 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 non-integer numeric data element may also be defined in the CDM XML Schema.

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

6.4.2.3 Text value data shall follow the conventions of the *string* data type per reference [4]. Additional restrictions on the values permitted for any data element may also be defined in the CDM XML Schema.

NOTE – 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.

6.4.2.4 In value fields that represent a time tag, values shall follow the conventions of the *ndm:epochType* data type used in all CCSDS NDM/XML schemas. This data type supports the options specified in 6.3.2.6.

6.4.3 CDM UNITS IN XML

CDM units shall be expressed as attributes in XML keyword tags in the form 'units="*unit-notation*"', where *unit-notation* conforms to the convention stated in 1.4.1.1.

NOTE – 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>

6.4.4 CDM COMMENTS IN XML

Comments must be displayed as values between the <COMMENT> and </COMMENT> tags.

ANNEX A

IMPLEMENTATION CONFORMANCE STATEMENT PROFORMA

(NORMATIVE)

A1 INTRODUCTION

A1.1 OVERVIEW

This annex provides the Implementation Conformance Statement (ICS) Requirements List (RL) for an implementation of *Conjunction Data Message* (CCSDS 508.0). The ICS for an implementation is generated by completing the RL in accordance with the instructions below. An implementation shall satisfy the mandatory conformance requirements referenced in the RL.

The RL in this annex is blank. An implementation's completed RL is called the ICS. The ICS states which capabilities and options have been implemented. The following can use the ICS:

– the implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight;

– a supplier or potential acquirer of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard ICS proforma;

– a user or potential user of the implementation, as a basis for initially checking the possibility of interworking with another implementation (it should be noted that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible ICSes);

– a tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A1.2 ABBREVIATIONS AND CONVENTIONS

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

<u>Item Column</u>

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

Feature Column

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

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

Keyword Column

The keyword column contains, where applicable, the CDM keyword associated with the feature.

Reference Column

The reference column indicates the relevant subsection or table in *Conjunction Data Message* (CCSDS 508.0) (this document).

Status Column

The status column uses the following notations:

M mandatory.

O optional.

Support Column Symbols

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

Y Yes, supported by the implementation.

N No, not supported by the implementation.

N/A Not applicable.

A1.3 INSTRUCTIONS FOR COMPLETING THE RL

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

A2 ICS PROFORMA FOR CONJUNCTION DATA MESSAGE

A2.1 GENERAL INFORMATION

A2.1.1 Identification of ICS

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

A2.1.2 Identification of Implementation Under Test (IUT)

Implementation name	
Implementation version	
Special Configuration	
Other Information	

A2.1.3 Identification of Supplier

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

A2.1.4 Document Version

CCSDS 508.0 Document Version	
Have any exceptions been required? (Note: A YES answer means that the implementation does not conform to the Recommended Standard. Non-supported mandatory capabilities are to be identified in the ICS, with an explanation of why the implementation is non-conforming.	Yes _____ No_____

A2.1.5 Requirements List

Item	Feature	Keyword	Reference	Status	Support
1	CDM Header	N/A	Table 3-1	M	
2	CDM version	CCSDS_CDM_VERS	Table 3-1	M	
3	Comment	COMMENT	Table 3-1	O	
4	Message creation date/time	CREATION_DATE	Table 3-1	M	
5	Message originator	ORIGINATOR	Table 3-1	M	
6	Spacecraft name(s)	MESSAGE_FOR	Table 3-1	O	
7	Unique message identifier	MESSAGE_ID	Table 3-1	M	
8	CDM Relative Metadata and Relative Data	N/A	Table 3-2	M	
9	Comment	COMMENT	Table 3-2	O	
10	Time of closest approach	TCA	Table 3-2	M	
11	Miss distance at TCA	MISS_DISTANCE	Table 3-2	M	
12	Relative speed at TCA	RELATIVE_SPEED	Table 3-2	O	
13	Relative position of Object 2 with respect to Object 1	RELATIVE_POSITION_R, RELATIVE_POSITION_T, RELATIVE_POSITION_N	Table 3-2	O	
14	Relative velocity of Object 2 with respect to Object 1	RELATIVE_VELOCITY_R, RELATIVE_VELOCITY_T, RELATIVE_VELOCITY_N	Table 3-2	O	
15	Conjunction assessment screening period start/stop times	START_SCREEN_PERIOD, STOP_SCREEN_PERIOD	Table 3-2	O	
16	Object1 centered screening volume reference frame, shape, and dimensions	SCREEN_VOLUME_FRAME, SCREEN_VOLUME_SHAPE, SCREEN_VOLUME_X, SCREEN_VOLUME_Y, SCREEN_VOLUME_Z	Table 3-2	O	
17	Screening volume entry/exit times for Object2	SCREEN_ENTRY_TIME, SCREEN_EXIT_TIME	Table 3-2	O	
18	Probability that Object1 and Object2 will collide	COLLISION_PROBABILITY	Table 3-2	O	
19	Method that was used to calculate collision probability	COLLISION_PROBABILITY_METHOD	Table 3-2	O	
20	CDM Metadata	N/A	Table 3-3	M	
21	Comment	COMMENT	Table 3-3	O	
22	Specifies object (1 or 2) to which metadata/data apply	OBJECT	Table 3-3	M	
23	Satellite catalog designator for the object	OBJECT_DESIGNATOR	Table 3-3	M	
24	Satellite catalog used for the object	CATALOG_NAME	Table 3-3	M	
25	Spacecraft name for the object	OBJECT_NAME	Table 3-3	M	
26	Full international designator for the object	INTERNATIONAL_DESIGNATOR	Table 3-3	M	
27	Type of space object	OBJECT_TYPE	Table 3-3	O	
28	Contact information for the object's owner/operator	OPERATOR_CONTACT_POSITION, OPERATOR_ORGANIZATION, OPERATOR_PHONE, OPERATOR_EMAIL	Table 3-3	O	

Item	Feature	Keyword	Reference	Status	Support
29	Name of the external ephemeris file used, if any.	EPHEMERIS_NAME	Table 3-3	M	
30	Describes how covariance matrix was derived	COVARIANCE_METHOD	Table 3-3	M	
31	Object's maneuver capacity	MANEUVERABLE	Table 3-3	M	
32	Defines the central body about which Object1/2 orbit	ORBIT_CENTER	Table 3-3	O	
33	Name of reference frame in which state vector is given	REF_FRAME	Table 3-3	M	
34	Gravity model used for OD	GRAVITY_MODEL	Table 3-3	O	
35	Atmospheric density model used for OD of the object	ATMOSPHERIC_MODEL	Table 3-3	O	
36	N-body gravitational perturbations used for OD	N_BODY_PERTURBATIONS	Table 3-3	O	
37	Indicates if solar radiation pressure perturbations were used in OD (Y/N)	SOLAR_RAD_PRESSURE	Table 3-3	O	
38	Indicates if solid Earth and ocean tides were used in OD (Y/N)	EARTH_TIDES	Table 3-3	O	
39	Indicates if in-track thrust modeling was used in OD (Y/N)	INTRACK_THRUST	Table 3-3	O	
40	CDM Data	N/A	Table 3-4	M	
41	Comment	COMMENT	Table 3-4	O	
42	Orbit Determination Parameters	N/A	Table 3-4	O	
43	Comment	COMMENT	Table 3-4	O	
44	Interval containing last accepted observation	TIME_LASTOB_START, TIME_LASTOB_END	Table 3-4	O	
45	Recommended/actual OD time span for object	RECOMMENDED_OD_SPAN, ACTUAL_OD_SPAN	Table 3-4	O	
46	Number of observations available/accepted in OD	OBS_AVAILABLE, OBS_USED	Table 3-4	O	
47	Number of sensor tracks available/accepted in OD	TRACKS_AVAILABLE, TRACKS_USED	Table 3-4	O	
48	Percentage of residuals accepted in OD	RESIDUALS_ACCEPTED	Table 3-4	O	
49	Weighted RMS of the residuals from OD	WEIGHTED_RMS	Table 3-4	O	
50	Additional Modeling Parameters	N/A	Table 3-4	O	
51	Comment	COMMENT	Table 3-4	O	
52	Actual area of the object	AREA_PC	Table 3-4	O	
53	Effective area of object exposed to atmospheric drag	AREA_DRG	Table 3-4	O	
54	Effective area of object exposed to solar radiation pressure	AREA_SRP	Table 3-4	O	
55	Mass of the object	MASS	Table 3-4	O	

Item	Feature	Keyword	Reference	Status	Support
56	Object's C_D•A/m and C_R•A/m used to propagate state vector covariance to TCA	CD_AREA_OVER_MASS, CR_AREA_OVER_MASS	Table 3-4	O	
57	Object's acceleration due to in-track thrust used to propagate state vector/covariance to TCA	THRUST_ACCELERATION	Table 3-4	O	
58	Specific Energy Dissipation Rate (SEDR)	SEDR	Table 3-4	O	
59	State Vector	N/A	Table 3-4	M	
60	Comment	COMMENT	Table 3-4	O	
61	Object Position Vector	X, Y, Z	Table 3-4	M	
62	Object Velocity Vector	X_DOT, Y_DOT, Z_DOT	Table 3-4	M	
63	Covariance Matrix	NA	Table 3-4	M	
64	Comment	COMMENT	Table 3-4	O	
65	Position/velocity 6×6 covariance matrix	CR_R, CT_R, CT_T, CN_R, CN_T, CN_N, CRDOT_R, CRDOT_T, CRDOT_N, CRDOT_RDOT, CTDOT_R, CTDOT_T, CTDOT_N, CTDOT_RDOT, CTDOT_TDOT, CNDOT_R, CNDOT_T, CNDOT_N, CNDOT_RDOT, CNDOT_TDOT, CNDOT_NDOT	Table 3-4	M	
66	Covariance matrix row 7 (Drag related)	CDRG_R, CDRG_T, CDRG_N, CDRG_RDOT, CDRG_TDOT, CDRG_NDOT, CDRG_DRG	Table 3-4	O	
67	Covariance matrix row 8 (Solar Radiation Pressure related)	CSRP_R, CSRP_T, CSRP_N, CSRP_RDOT, CSRP_TDOT, CSRP_NDOT, CSRP_DRG, CSRP_SRP	Table 3-4	O	
68	Covariance matrix row 9 (In-track Thrust related)	CTHR_R, CTHR_T, CTHR_N, CTHR_RDOT, CTHR_TDOT, CTHR_NDOT, CTHR_DRG, CTHR_SRP, CTHR_THR	Table 3-4	O	

ANNEX B

SECURITY, SANA, AND PATENT CONSIDERATIONS

(INFORMATIVE)

B1 SECURITY CONSIDERATIONS

B1.1 ANALYSIS OF SECURITY CONSIDERATIONS

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

B1.2 CONSEQUENCES OF NOT APPLYING SECURITY TO THE TECHNOLOGY

The consequences of not applying security to the systems and networks on which this Recommended 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 Recommended Standard is implemented could include compromise or loss of the mission if malicious tampering of a particularly severe nature occurs.

B1.3 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 Recommended Standard. It is strongly recommended that potential threats or attack scenarios applicable to the systems and networks on which this Recommended Standard is implemented be addressed by the management of those systems and networks.

B1.4 DATA PRIVACY

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

B1.5 DATA INTEGRITY

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

B1.6 AUTHENTICATION OF COMMUNICATING ENTITIES

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

B1.7 DATA TRANSFER BETWEEN COMMUNICATING ENTITIES

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

B1.8 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.

B1.9 AUDITING OF RESOURCE USAGE

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

B1.10 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.

B1.11 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 Recommended Standard could be specified in an ICD.

B2 SANA CONSIDERATIONS

The following CDM-related items will be registered with the SANA Operator. The registration rule for new entries in the registry is the approval of new requests by the CCSDS Navigation Working Group chair. New requests for this registry should be sent to SANA (mailto:info@sanaregistry.org).

– The CDM XML schema;

– A transform from the CDM XML to the CDM KVN version;

– Values for the keywords ORIGINATOR and CATALOG_NAME; and

– A list of options for the COLLISION_PROBABILITY_METHOD keyword.

B3 PATENT CONSIDERATIONS

The recommendations of this document have no patent issues.

ANNEX C

ABBREVIATIONS AND ACRONYMS

(INFORMATIVE)

ASCII	American Standard Code for Information Interchange
CA	Conjunction Assessment
CCSDS	Consultative Committee for Space Data Systems
CDM	Conjunction Data Message
DRG	Atmospheric Drag
EME2000	Earth Mean Equator and Equinox of J2000 (Epoch J2000)
GCRF	Geocentric Celestial Reference Frame
ICD	Interface Control Document
ITRF	International Terrestrial Reference Frame
KVN	Keyword = Value Notation
NDM	Navigation Data Message
O/O	Owner/Operator
OD	Orbit Determination
OBS	Observations
RCS	Radar Cross Section
RMS	Root Mean Square
RTN	Radial, Transverse and Normal
SANA	Space Assigned Numbers Authority
SEDR	Specific Energy Dissipation Rate
SI	International System of Units
SRP	Solar Radiation Pressure
TCA	Time of Closest Approach
THR	Thrust
TVN	Transverse, Velocity and Normal
UTC	Coordinated Universal Time
XML	Extensible Markup Language
XSLT	Extensible Stylesheet Language Transformations

ANNEX D

RATIONALE AND REQUIREMENTS FOR CONJUNCTION DATA MESSAGES

(INFORMATIVE)

D1 OVERVIEW

This annex presents the rationale behind the design of the Conjunction Data Message.

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

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

b) Desirable Characteristics, which are not requirements, but are felt to be important or useful features of the Recommended Standard.

D2 PRIMARY REQUIREMENTS ACCEPTED BY THE CDM

Table D-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 satellite owner/operators and other authorized parties.	The CCSDS objective of promoting interoperability is not met if messages are produced using esoteric or proprietary data structures.	3.1.2
CDM-P03	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-P04	The CDM shall clearly and unambiguously identify the two objects involved in a conjunction.	This information is fundamental to the owner/operators of the objects in the conjunction. Cited as required in ISO 16158 (reference [F2]).	Table 3-3
CDM-P05	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 [F2]).	Table 3-2
CDM-P06	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.	6.3.2.6, 6.4.2.4,
CDM-P07	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 owner/operators who wish to perform an independent assessment of the conjunction and/or the probability of collision. Cited as desirable in ISO 16158 (reference [F2]).	Table 3-4

Reqt #	Requirement	Rationale	Trace
CDM-P08	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 [F2]).	Table 3-2
CDM-P09	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. Cited as required in ISO 16158 (reference [F2]).	Table 3-3
CDM-P10	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, 6.3.3, 6.4.3, Table 3-2
CDM-P11	The CDM shall provide a covariance matrix that includes at least 6×6 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 [F2]).	Table 3-4
CDM-P12	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 [F2]).	Table 3-3
CDM-P13	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 central body 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 3-3
CDM-P14	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. The probability of collision is cited as desirable in ISO 16158 (reference [F2]).	Table 3-2, Table 3-3, Table 3-4

Reqt #	Requirement	Rationale	Trace
CDM-P15	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 owner/operators may not be able to perform the required computations.	Table 3-2, Table 3-3, Table 3-4
CDM-P16	The CDM shall provide an indicator as to the ephemerides that were used in identifying the conjunction.	Informs the recipient as to whether the ephemeris used was owner/operator supplied or was created by the CDM originator.	Table 3-3

Table D-2: Desirable Characteristics

ID	Requirement	Rationale	Trace
CDM-D01	The CDM should be extensible with no disruption to existing users/uses.	Space agencies and owner/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 Recommended Standards developed by a given CCSDS Working Group will be consistent.	2.2
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
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 [F2]).	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

ID	Requirement	Rationale	Trace
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 [F2]).	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 owner/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. Cited as desirable by ISO 16158 (reference [F2]).	Table 3-2
CDM-D09	The CDM shall be provided using file name syntax and length that do not violate computer constraints for those computing environments in use by satellite owner/operators and other authorized parties.	The CCSDS objective of promoting interoperability is not met if messages are provided using nonstandard file-name syntax or length.	3.1.2

ANNEX E

CONJUNCTION INFORMATION DESCRIPTION

(INFORMATIVE)

E1 RELATIVE DATA

TCA (Time of Closest Approach): 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 value associated with the COLLISION_PROBABILITY keyword. Example options are 'FOSTER-1992' (see reference [F4]), 'CHAN-1997' (see reference [F8]), 'PATERA-2001' (see reference [F6]), 'ALFANO-2005' (see reference [F7]), and 'MCKINLEY-2006' (see reference [F9]). A list of currently registered options is available on the SANA Registry at http://sanaregistry.org. (To register a new option for this keyword, see annex B, subsection B2.)

MISS_DISTANCE: The miss distance is the norm of the relative position vector. It indicates how close the two objects are at the time of the predicted encounter.

RELATIVE_SPEED: The relative speed is the norm of the relative velocity vector. It indicates 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: Object-centered coordinate system. The Object1-centered RTN coordinate frame: R (Radial) is the unit vector in the radial direction pointed outward from the center of the central body, T (Transverse) is the unit vector perpendicular to the R vector in the direction of the spacecraft velocity, and N (Normal) is the unit vector normal to the satellite's inertial orbit plane (in the direction of the satellite's angular momentum) that completes the right-hand coordinate frame (see figure E-1).

TVN Coordinate Frame: Object-centered coordinate system. The Object1-centered TVN coordinate frame is defined as: V (Velocity) is the unit vector in the inertial 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 E-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 the TVN frame is anchored on the unit inertial 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 non-circular orbits where the user would like one coordinate axis 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.

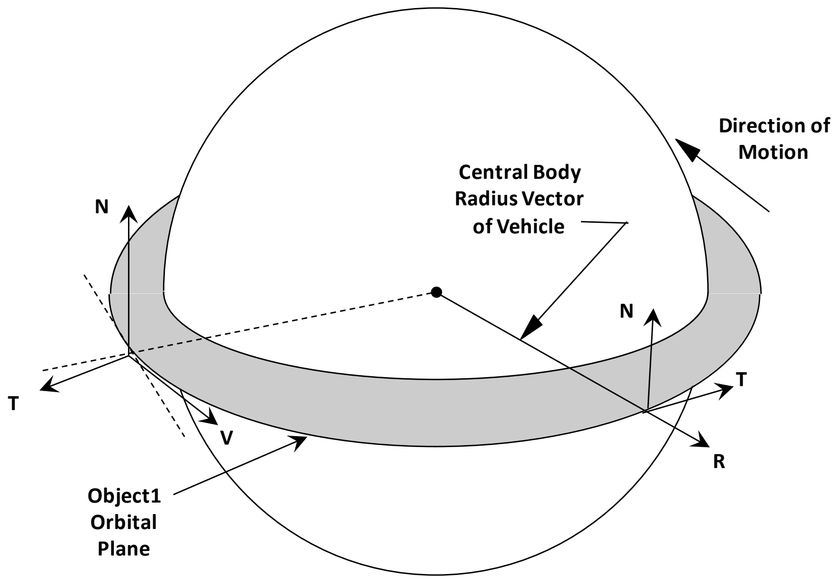

Figure E-1: Definition of the RTN and TVN Coordinate Frames

SCREEN_VOLUME_SHAPE/SCREEN_VOLUME: Shape (ellipsoid or box) 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).

E2 ORBIT DETERMINATION PARAMETERS

Observation: 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_START and TIME_LASTOB_END: The start and end of a time interval (UTC) that contains the time of the last accepted observation (see 6.3.2.6 for formatting rules). For an exact time, the time interval is of zero duration (i.e., TIME_LASTOB_START = TIME_LASTOB_END).

RECOMMENDED_OD_SPAN: How many days of observations were recommended for the OD of the object.

ACTUAL_OD_SPAN: The actual time span used for the OD of the object based on the observations available and the RECOMMENDED_OD_SPAN.

OBS_AVAILABLE: The number of observations, for the recommended time span, that were available for the OD.

OBS_USED: The number of observations, for the recommended time span, that were accepted for the OD.

Sensor Track: 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: 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: 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.

WEIGHTED_RMS:

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

Where

y_i is the observation measurement at the ith time;

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

$w_i = \dfrac{1}{\sigma_i^2}$ is the weight 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.

E3 MODEL PARAMETERS

GRAVITY_MODEL: 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: The atmospheric density model used in the state vector update.

N_BODY_PERTURBATIONS: 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: Whether perturbations due to solar radiation pressure were included in the state vector update.

EARTH_TIDES: Whether perturbations due to solid Earth and ocean tides were included in the state vector update.

E4 ADDITIONAL PARAMETERS

AREA_PC: The actual area of the object (m**2). The area could be known by the owner/operator of the satellite or defined by using a Radar Cross Section (RCS) as in the case of debris. If the value of the area is unknown or not available, '0.0' may be displayed. This parameter can be useful for calculating the collision probability.

AREA_DRG: The effective area of the object (m**2) exposed to atmospheric drag.

AREA_SRP: The effective area of the object (m**2) exposed to solar radiation pressure.

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

CR_AREA_OVER_MASS: The coefficient of 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 $C_R \cdot A/m$, calculated using solar flux at 1 AU, where C_R is the solar radiation pressure coefficient, A is the effective area of the object exposed to solar radiation pressure 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 (Specific Energy Dissipation Rate): The amount of energy (W/kg) 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.

E5 COVARIANCE MATRIX

The covariance matrix is obligatory for the position and velocity terms, given in the lower triangular form of a 6×6 matrix. If any of the diagonal terms are zero, the entire row and column of the matrix related to that term should be discounted. Optional terms for CD_AREA_OVER_MASS (denoted 'DRG'), CR_AREA_OVER_MASS (denoted 'SRP'), and THRUST_ACCELERATION (denoted 'THR') can be added to the 6×6 matrix, in the lower triangular form, to complete a 9×9 matrix. If any element in any of these rows (7, 8, or 9) is provided, then all of the elements for that row and all preceding rows need to 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 originator's propagator model available (along with the appropriate CD_AREA_OVER_MASS and/or CR_AREA_OVER_MASS and/or THRUST_ACCELERATION terms), can correctly propagate the 6×6 position and velocity covariance to another time point.

ANNEX F

INFORMATIVE REFERENCES

(INFORMATIVE)

[F1] *Navigation Data—Definitions and Conventions*. Issue 3. Report Concerning Space Data System Standards (Green Book), CCSDS 500.0-G-3. Washington, D.C.: CCSDS, May 2010.

[F2] *Space Systems—Avoiding Collisions with Orbiting Objects*. International Standard, ISO/TR 16158:2013. Geneva: ISO, 2013.

[F3] *Astrodynamics—Propagation Specifications, Technical Definitions, and Recommended Practices*. ANSI/AIAA S-131-2010. Reston, Virginia: AIAA, 2010.

[F4] J. L. Foster and H. S. Estes. *A Parametric Analysis of Orbital Debris Collision Probability and Maneuver Rate for Space Vehicles*. NASA/JSC-25898. Houston, Texas: NASA Johnson Space Flight Center, August 1992.

[F5] Ken Chan. "Collision Probability Analyses for Earth Orbiting Satellites." In *Space Cooperation into the 21st Century: 7th AAS/JRS/CSA Symposium, International Space Conference of Pacific-Basin Societies (ISCOPS; formerly PISSTA) (July 15-18, 1997, Nagasaki, Japan)*. 1033–1050. Edited by Peter M. Bainum, et al.. Advances in the Astronautical Sciences Series 96. San Diego, California: Univelt, 1997.

[F6] Russell P. Patera. "General Method for Calculating Satellite Collision Probability." *Journal of Guidance, Control, and Dynamics* 24, no. 4 (July–August 2001): 716-722.

[F7] Salvatore Alfano. "A Numerical Implementation of Spherical Object Collision Probability." *The Journal of the Astronautical Sciences* 53, no. 1 (January-March 2005): 103-109.

[F8] Salvatore Alfano. "Review of Conjunction Probability Methods for Short-Term Encounters." In *Proceedings of the 17th AAS/AIAA Space Flight Mechanics Meeting (January 28 - February 1, 2007, Sedona, Arizona)*. 719–747. Edited by Maruthi R. Akella, et al.. Advances in the Astronautical Sciences Series 127. San Diego, California: Univelt, 2007.

[F9] David McKinley. "Development of a Nonlinear Probability of Collision Tool for the Earth Observing System." In *Proceedings of AIAA/AAS Astrodynamics Specialist Conference and Exhibit (21 August 2006–24 August 2006, Keystone, Colorado)*. Reston, Virginia: AIAA, 2006.

[F10] K. Alfriend, et al. "Probability of Collision Error Analysis." *Space Debris* 1, no. 1 (1999): 21-35.

[F11] *IERS Conventions (2010)*. Edited by Gérard Petit and Brian Luzum. IERS Technical Note No. 32. Frankfurt am Main, Germany: Bundesamt für Kartographie und Geodäsie, 2010.