

Recommendation for Space Data System Standards

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| Conjunction Data Message |

Recommended Standard

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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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# Introduction

## 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:

1. facilitate interoperability and enable consistent warning between data originators who supply CA and the satellite owner/operators who use it;
2. facilitate automation for the CA processes; and
3. 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 E). Also included are informative descriptions of conjunction information pertinent to performing CA (see annex F).

## 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 F.

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, the presence of user defined keywords allows other information to be exchanged after being specified in an Interface Control Document (ICD) written jointly by the service originator and recipients. The CCSDS Navigation Working Group should be notified of new optional keywords for possible inclusion in future revisions of the standard.

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 transmissionnor 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 H).

## 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 values for selected keywords.

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

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

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

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

Annex G provides CDM examples in both KVN and XML formats.

Annex H provides informative references.

Annex I provides items for an Interface Control Document (ICD)

Annex J describes changes versus previous versions of the CDM.

## Conventions and DEFINITIONS

### notation

#### 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;
* deg: degrees;
* n/a: (units are not applicable).

#### General

The following notational conventions are used in this document:

1. multiplication of units is denoted with a single asterisk ‘\*’ (e.g., ‘kg\*s’);
2. exponents of units are denoted with a double asterisk ‘\*\*’ (e.g., m2 = m\*\*2);
3. division of units is denoted with a single forward slash ‘/’ (e.g., m/s).

### NOMENCLATURE

#### General

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

#### Normative Text

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

1. the words ‘shall’ and ‘must’ imply a binding and verifiable specification;
2. the word ‘should’ implies an optional, but desirable, specification;
3. the word ‘may’ implies an optional specification;
4. 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.

#### 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.

### Other CONVENTIONS

#### 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’.

#### 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.

## 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)*. 9th ed. Sèvres, France: BIPM, 2019.

[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.

[6] *XML Specification for Navigation Data Messages*. Issue 3. Recommendation for Space Data System Standards (Blue Book), CCSDS 505.0-B-3. Washington, D.C.: CCSDS, May 2023.

[7] *“Online Index of Objects Launched into Outer Space.”* United Nations Office for Outer Space Affairs (UNOOSA). https://www.unoosa.org/oosa/osoindex/search-ng.jspx.

[8] *IEEE Standard for Floating-Point Arithmetic*, IEEE Computer Society, IEEE Std 754-2019, Approved 13 June 2019.

# Overview

## 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.

## 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 [H11], EME2000);
* Object1/Object2 covariances at TCA with respect to an object centered reference frame;
* the relative position/velocity at TCA 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.).

# CDM CONTENT/STRUCTURE IN KVN

## GENERAL

The CDM in KVN shall consist of digital data represented as ASCII text lines. As depicted in Table 3‑1, the lines constituting a CDM shall be represented as a combination of the following:

1. a header;
2. relative motion metadata/data;
3. metadata/data for Object1;
4. metadata/data for Object2; and
5. user defined parameters.

Table 3‑1 : CDM File Layout and Ordering Specification

|  |  |  |
| --- | --- | --- |
| **Section** | | **Content** |
| CDM Header | | A single header of the message |
| CDM Relative Motion Metadata | | Metadata/data describing relative motion of Object2 with respect to Object1 |
| Object1 | Metadata | Metadata about Object1 |
| Data | Data for Object1 |
| Object2 | Metadata | Metadata about Object2 |
| Data | Data for Object2 |
| User Defined Parameters (Optional) | | A user-defined parameters section containing data the existing CDM keywords do not accommodate |

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).

The CDM shall be plain text consisting of CA data for a single conjunction event.

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

## CDM HEADER

The CDM header shall consist of the KVN elements defined in table 3‑2, which specifies for each KVN header item:

1. the keyword to be used;
2. a short description of the item;
3. examples of allowed values; and
4. whether the item is mandatory (M), optional (O) or conditional (C). Conditional indicates that the item is mandatory if specified conditions are met (e.g., providing all covariance matrix elements if any are provided).

Table 3‑2 : CDM KVN Header

| **Keyword** | **Description** | **Example of Values** | **MOC** |
| --- | --- | --- | --- |
| 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. | 2.0 | M |
| COMMENT | (See 6.3.4 for formatting rules.) | COMMENT This is a comment | O |
| CLASSIFICATION | User-defined free-text message classification or caveats of this CDM. It is recommended that selected values be pre-coordinated between exchanging entities by mutual agreement. | UNCLASSIFIED  “Operator-proprietary data; secondary distribution not permitted” | O |
| CREATION\_DATE | Message creation date/time in Coordinated Universal Time (UTC). (See 6.3.2.9 for formatting rules.) | 2010-03-12T22:31:12.000  2010-071T22:31:12.000 | M |
| 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 6.2.2.2 for formatting rules.) | See SANA | M |
| MESSAGE\_FOR | Spacecraft name(s) for which the CDM is provided. | SPOT  ENVISAT  IRIDIUM  INTELSAT | O |
| 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 6.2.2.2 for formatting rules.) | 201113719185  ABC-12\_34 | M |

## CDM RELATIVE METADATA/DATA

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

1. the keyword to be used;
2. a short description of the item;
3. the units to be used if applicable; and
4. whether the item is mandatory (M), optional (O) or conditional (C). Conditional indicates that the item is mandatory if specified conditions are met (e.g., providing all covariance matrix elements if any are provided).

Table 3‑3 : CDM KVN Relative Motion Metadata/Data

| **Keyword** | **Description** | **Units** | **MOC** |
| --- | --- | --- | --- |
| COMMENT | (See 6.3.4 for formatting rules.) | n/a | O |
| CONJUNCTION\_ID | Originator’s ID that uniquely identifies the conjunction to which the message refers, e.g. 20200610T10hz\_SKYNET5B\_GORIZONT9 (See 6.2.2.2 for formatting rules). | n/a | O |
| TCA | The date and time in UTC of the closest approach. 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. (See 6.3.2.9 for formatting rules.) | n/a | M |
| MISS\_DISTANCE | The length of the relative position vector. It indicates how close the two objects are at TCA. Data type = double. | m | M |
| MAHALANOBIS\_DISTANCE | The length of the relative position vector, normalized to one-sigma dispersions of the combined error covariance in the direction of the relative position vector, as defined in informative annex F1. Data type = double. | n/a | O |
| RELATIVE\_SPEED | The length 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 | O |
| RELATIVE\_POSITION\_R | The radial component of Object2’s position relative to the Object1 centered Radial, Transverse, and Normal (RTN) coordinate frame. (See annex F for definition.) Data type = double. | m | O |
| RELATIVE\_POSITION\_T | The transverse component of Object2’s position relative to the Object1 centered RTN coordinate frame. (See annex F for definition.) Data type = double. | m | O |
| RELATIVE\_POSITION\_N | The normal component of Object2’s position relative to the Object1 centered RTN coordinate frame. (See annex F for definition.) Data type = double. | m | O |
| RELATIVE\_VELOCITY\_R | The radial component of Object2’s velocity relative to the Object1 centered RTN coordinate frame. (See annex F for definition.) Data type = double. | m/s | O |
| RELATIVE\_VELOCITY\_T | The transverse component of Object2’s velocity relative to the Object1 centered RTN coordinate frame. (See annex F for definition.) Data type = double. | m/s | O |
| RELATIVE\_VELOCITY\_N | The normal component of Object2’s velocity relative to the Object1 centered RTN coordinate frame. (See annex F for definition.) Data type = double. | m/s | O |
| APPROACH\_ANGLE | The angle between the inertial velocity vector of Object1 and the relative velocity vector of Object2 with respect to Object1 in the inertial frame. 0 degrees reflects “overtaking” and 180 degrees reflects “head-on” condition. | deg | O |
| START\_SCREEN\_PERIOD | The start time in UTC of the screening period for the conjunction assessment. (See 6.3.2.9 for formatting rules.) | n/a | O |
| STOP\_SCREEN\_PERIOD | The stop time in UTC of the screening period for the conjunction assessment. (See 6.3.2.9 for formatting rules.) | n/a | O |
| SCREEN\_TYPE | The type of screening to be used. The value(s) can be any combination of the following: {SHAPE, PC, PC\_MAX} as comma delimited values.  For collision probability (PC) or maximum collision probability (PC\_MAX) screening, estimated collision probability values are compared against the specified SCREEN\_PC\_THRESHOLD. | n/a | O |
| SCREEN\_VOLUME\_SHAPE | The type of screening metric or algorithm used, to include SPHERE, ELLIPSOID, or BOX.  (Condition: Mandatory if SCREEN\_TYPE = SHAPE) | n/a | C |
| SCREEN\_VOLUME\_RADIUS | The radius of the screening volume. Data type = double.  (Condition: Mandatory if SCREEN\_VOLUME\_SHAPE = SPHERE) | m | C |
| SCREEN\_VOLUME\_FRAME | Name of the Object1 centered reference frame in which the screening volume data are given. Available options are RTN and TVN (Transverse, Velocity, and Normal).  (Condition: Mandatory if SCREEN\_VOLUME\_SHAPE = ELLIPSOID or BOX) | n/a | C |
| 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.  (Condition: Mandatory if SCREEN\_VOLUME\_SHAPE = ELLIPSOID or BOX) | m | C |
| 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.  (Condition: Mandatory if SCREEN\_VOLUME\_SHAPE = ELLIPSOID or BOX) | m | C |
| SCREEN\_VOLUME\_Z | The N component size of the screening volume in the SCREEN\_VOLUME\_FRAME. Data type = double.  (Condition: Mandatory if SCREEN\_VOLUME\_SHAPE = ELLIPSOID or BOX) | m | C |
| SCREEN\_ENTRY\_TIME | The time in UTC when Object2 enters the screening volume (See 6.3.2.9 for formatting rules).  (Condition: Mandatory if SCREEN\_VOLUME\_SHAPE being present) | n/a | C |
| SCREEN\_EXIT\_TIME | The time in UTC when Object2 exits the screening volume (See 6.3.2.9 for formatting rules).  (Condition: Mandatory if SCREEN\_VOLUME\_SHAPE being present) | n/a | C |
| SCREEN\_PC\_THRESHOLD | The collision probability screening threshold used to identify this conjunction. Data type = double.  (Condition: Mandatory for SCREEN\_TYPE = PC or PC\_MAX) | n/a | C |
| COLLISION\_PERCENTILE | An array of 1 to n elements indicating the percentile(s) for which estimates of the collision probability are provided in the COLLISION\_PROBABILITY variable. A COLLISION\_PERCENTILE of 50% corresponds to the median (or typical) collision probability. A COLLISION\_PERCENTILE of 20% indicates the collision probability that equals or exceeds 20% of all estimated collision probability values drawn from the full ensemble of possible Pc values. The entry consists of a single line of elements separated by white-spaces. Data type = integer array. | n/a | O |
| COLLISION\_PROBABILITY | If COLLISION\_PERCENTILE is present,  an array of 1 to n elements specifying the estimated collision probability at the specified COLLISION\_PERCENTILE value (each element value in the range 0.0 to 1.0), that Object1 and Object2 will collide, accounting for estimated uncertainties in covariance realism and variability in Object1 and Object2 orientation at TCA with respect to the encounter plane. For example, at a COLLISION\_PERCENTILE of 50%, the median (or typical) collision probability value is estimated. The entry consists of a single line of elements separated by white-spaces. Data type = double array.  If COLLISION\_PERCENTILE is not present, the best estimate of probability at the instantaneous epoch of interest (denoted ‘p’ where 0.0<=p<=1.0), that Object1 and Object2 will collide, accounting for estimated uncertainties in covariance realism and variability in Object1 and Object2 orientation at TCA with respect to the encounter plane.  Data type = double. | n/a | O |
| COLLISION\_PROBABILITY\_METHOD | The method that was used to calculate the COLLISION\_PROBABILITY. Example options are ‘FOSTER-1992’ (see reference [H4]), ‘CHAN-1997’ (see reference [H5]), ‘PATERA-2001’ (see reference [H6]), ‘ALFANO-2005’ (see reference [H7]), and ‘MCKINLEY-2006’ (see reference [H9]). A list of currently registered options is available on the SANA Registry at <https://sanaregistry.org/r/cdm_cpm/>. | n/a | O |
| COLLISION\_MAX\_PROBABILITY | The maximum collision probability that Object1 and Object2 will collide, as assessed via COLLISION\_ MAX\_PC\_METHOD. Data type = double. | n/a | O |
| COLLISION\_MAX\_PC\_METHOD | The method that was used to calculate the COLLISION\_MAX\_PROBABILITY. Example options are ‘SCALE\_COMBINED\_COVAR’ (see Eqn. 34 of [H16]) and ‘SCALE\_INDIV\_COVAR’ (see reference [H8]) | n/a | O |
| SEFI\_COLLISION\_PROBABILITY | If COLLISION\_PERCENTILE is present,  an array of 1 to n elements specifying the space environment fragmentation impact (SEFI) adjusted estimate of collision probability (each element value in the range 0.0 to 1.0), that Object1 and Object2 will collide, accounting for estimated uncertainties in covariance realism and variability in Object1 and Object2 orientation at TCA with respect to the encounter plane for each percentile specified in COLLISION\_PERCENTILE. The entry consists of a single line of elements separated by white-spaces. Data type = double array.  If COLLISION\_PERCENTILE is not present, the best estimate (median) space environment fragmentation impact adjusted probability (denoted ‘p’ where 0.0<=p<=1.0), that Object1 and Object2 will collide, accounting for estimated uncertainties in covariance realism and variability in Object1 and Object2 orientation at TCA with respect to the encounter plane. Data type = double.  See annex F for an example of space environment fragmentation impact adjustment. | n/a | O |
| SEFI\_COLLISION\_PROBABILITY\_METHOD | The method that was used to calculate the SEFI\_COLLISION\_PROBABILITY. | n/a | O |
| SEFI\_FRAGMENTATION\_MODEL | Free text field containing the name of the space environment fragmentation model used (formatting rules specified in 6.2.2.2). | n/a | O |
| **Information about the previous and next messages to be issued** | | | |
| PREVIOUS\_MESSAGE\_ID | ID of previous CDM issued for event identified by CONJUNCTION\_ID. (See 6.2.2.2 for formatting rules.) | n/a | O |
| PREVIOUS\_MESSAGE\_EPOCH | UTC epoch (CREATION\_DATE) of the previous CDM issued for the event identified by CONJUNCTION\_ID. (See 6.3.2.9 for formatting rules.) | n/a | O |
| NEXT\_MESSAGE\_EPOCH | Scheduled UTC epoch of the next CDM associated with the event identified by CONJUNCTION\_ID. (See 6.3.2.9 for formatting rules.) | n/a | O |

## CDM OBJECT1 and OBJECT2 METADATA

The CDM metadata shall consist of the KVN elements defined in table 3‑4, which specifies for each KVN metadata item:

1. the keyword to be used;
2. a short description of the item;
3. normative values or examples of allowed values;
4. whether the item is mandatory (M), optional (O) or conditional (C). Conditional indicates that the item is mandatory if specified conditions are met (e.g., providing all covariance matrix elements if any are provided).

NOTE – Table 3‑4 and table 3‑5 will define the metadata and data sections associated with each object involved in the conjunction. The OBJECT keyword, which is specified in table 3‑4, will indicate whether metadata and data section relate to either Object 1 or Object 2.

Table 3‑4 : CDM KVN Metadata

| **Keyword** | **Description** | **Examples** | **MOC** |  |
| --- | --- | --- | --- | --- |
| COMMENT | (See 6.3.4 for formatting rules.) | COMMENT This is a comment | O |  |
| OBJECT | The object to which the metadata and data apply.  Value must be either OBJECT1 or OBJECT2. | OBJECT1 | M |  |
| OBJECT\_DESIGNATOR | Free text field specification of the unique satellite identification designator for the object, as reflected in the catalogue whose name is “CATALOG\_NAME”. If the ID is not known (uncorrelated object), “UNKNOWN” may be used. (see 6.2.2.2 for formatting rules.) | 22444  18SPCS 18571  UNKNOWN | M |  |
| CATALOG\_NAME | Free-text field containing the satellite catalog source (or source agency or operator, value to be drawn from the SANA registry list of Space Object Catalogs at <https://sanaregistry.org/r/space_object_catalog>, or alternatively, from the list of organizations listed in the ‘Abbreviation’ column of the SANA Organizations registry at <https://sanaregistry.org/r/organizations>) from which ‘OBJECT\_DESIGNATOR’ was obtained. (See 6.2.2.2 for formatting rules.)  June 2018  CCSDS 508.0-B-1 Cor. 1 | SATCAT | M |  |
| OBJECT\_NAME | Free text field containing the name of the object (formatting rules specified in 6.2.2.2). There is no CCSDS-based restriction on the value for this keyword, but it is recommended to use names from the UN Office of Outer Space Affairs designator index —reference [7], which include Object name and international designator of the participant. If the object name is not known (uncorrelated object), “UNKNOWN” may be used. | SPOT-7  ENVISAT  IRIDIUM NEXT-8  INTELSAT G-15  UNKNOWN | M |  |
| INTERNATIONAL\_DESIGNATOR | Free text field containing an international designator for the object as assigned by the UN Committee on Space Research (COSPAR). Such designator values have the following COSPAR format:  YYYY-NNNP{PP}, where:  YYYY = Year of launch.  NNN = Three-digit serial number of launch in year YYYY (with leading zeros).  P{PP} = At least one capital letter for the identification of the part brought into space by the launch.  In cases where the object has no international designator, the value UNKNOWN may be used. (See 6.2.2.2 for further formatting rules.) | 2002-021A  2002-009A  1997-020AA  1998-037ABC  2001-049PE  UNKNOWN | M |  |
| OBJECT\_TYPE | Specification of the type of object.  Value must be taken from the SANA registry for Object Types at <https://sanaregistry.org/r/object_types/>. | PAYLOAD | O |  |
| OPS\_STATUS | Specification of the operational status of the space object.  Value must be taken from the SANA registry for Operational Status at <https://sanaregistry.org/r/operational_status/>. | OPERATIONAL\_MANEUVERABLE | O | |
| OPERATOR\_CONTACT\_POSITION | Contact position of the owner/operator of the object. | ORBITAL SAFETY ANALYST (OSA)  NETWORK CONTROLLER | O |  |
| OPERATOR\_ORGANIZATION | Contact organization of the object. | EUMETSAT  ESA  INTELSAT  IRIDIUM | O |  |
| OPERATOR\_PHONE | Phone number of the contact position or organization for the object. | +49615130312 | O |  |
| OPERATOR\_EMAIL | Email address of the contact position or organization of the object. | JOHN.DOE@  SOMEWHERE.NET | O |  |
| 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.  Users are encouraged to use the ODM\_MSG\_LINK keyword (below) for the specification of Orbit Data Message (ODM) formatted ephemeris data. If ODM\_MSG\_LINK is used, then EPHEMERIS\_NAME shall be set to ODM. | EPH\_SAT\_A  NONE  ODM | M |  |
| ODM\_MSG\_LINK | Free text field containing a unique identifier of Orbit Data Message(s) that are linked (relevant) to this Conjunction Data Message.  (Condition: Mandatory if EPHEMERIS\_NAME=ODM) | ODM\_MSG\_35132.txt  ODM\_ID\_0572 | C | |
| ADM\_MSG\_LINK | Free text field containing a unique identifier of Attitude Data Message(s) (ADM) that are linked (relevant) to this Conjunction Data Message. | ATT\_MSG\_35132.txt  ATT\_ID\_0572 | O | |
| OBS\_BEFORE\_NEXT\_MESSAGE | Flag indicating whether new tracking observations are anticipated prior to the issue of the next CDM associated with the event specified by CONJUNCTION\_ID.  Value must be taken from the following list: {YES, NO, UNKNOWN} | YES | O | |
| 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.  Value must be taken from the following list: {CALCULATED,  DEFAULT} | CALCULATED | M |  |
| COVARIANCE\_SOURCE | A free text field which provides the source from which the covariance data used for the object originates. The purpose of this field addition is to highlight the method by which the covariance was derived. | O/O Covariance  Quadratic-Error Growth  HAC Covariance  Vector Covariance Message (VCM) | O | |
| MANEUVERABLE | The maneuver capacity of the object.  Value must be taken from the following list: {YES, NO, UNKNOWN} | YES | M |  |
| ORBIT\_CENTER | Origin of the CDM reference frame about which Object1 and Object2 orbit, which shall be a natural solar system body (planets, asteroids, comets, and natural satellites), including any planet barycenter or the solar system barycenter. Values should be taken from the SANA registry for Orbit Centers at <https://sanaregistry.org/r/orbit_centers/>.  If not specified, the center is assumed to be Earth. | EARTH  SUN  MOON  MARS | O |  |
| REF\_FRAME | Name of the reference frame in which the state vector data are provided.  The selected reference frame must be the same for both Object1 and Object2.  Value must be taken from the following list: {GCRF, EME2000, ITRF}  Reference frame definitions for these three frames may be found at the SANA registry for Celestial Body Reference Frames at <https://sanaregistry.org/r/celestial_body_reference_frames/>. | ITRF | M |  |
| ALT\_COV\_TYPE | Flag indicating the type of alternate covariance information provided.  Value must be taken from the following list: {XYZ, CSIG3EIGVEC3} | XYZ | O | |
| ALT\_COV\_REF\_FRAME | Name of the reference frame in which the alternate covariance data are given.  The selected reference frame must be the same for both Object 1 and Object 2 covariances.  Value must be taken from the following list: {GCRF, EME2000, ITRF}  Reference frame definitions for these three frames may be found at the SANA registry for Celestial Body Reference Frames at <https://sanaregistry.org/r/celestial_body_reference_frames/>.  (Condition: Mandatory if ALT\_COV\_TYPE present) | ITRF | C | |
| GRAVITY\_MODEL | The gravity model (selected from the accepted set of gravity model names enumerated in the SANA Registry of Gravity Models, located at:  <https://sanaregistry.org/r/gravity_models>, followed by the degree (D) and order (O) of the applied spherical harmonic coefficients used in the simulation.  NOTE – Specifying a zero value for “order” (e.g., 2D 0O) denotes zonals (J2 … JD) | EGM-96: 36D 36O WGS-84: 8D 0O  GGM-01: 36D 36O  TEG-4: 36D 36O | O |  |
| ATMOSPHERIC\_MODEL | Name of atmosphere model, which shall be selected from the accepted set of values enumerated in the SANA Registry of Atmosphere Models, located at:  <https://sanaregistry.org/r/atmosphere_models> | JACCHIA\_HASDM  MSIS-86  JR71  NONE | O |  |
| N\_BODY\_PERTURBATIONS | One or more (N-body) gravitational perturbations bodies used. Values, listed serially in comma-delimited fashion, denote a natural solar or extra-solar system body (stars, planets, asteroids, comets, and natural satellites). Accepted values are enumerated in the SANA Registry of Orbit Centers, located at <https://sanaregistry.org/r/orbit_centers/>. | MOON  SUN  JUPITER  NONE | O |  |
| SOLAR\_RAD\_PRESSURE | Indication of whether solar radiation pressure perturbations were used for the OD of the object.  Value must be taken from the following list: {YES, NO} | YES | O |  |
| EARTH\_TIDES | Indication of whether solid Earth and ocean tides were used for the OD of the object.  Value must be taken from the following list: {YES, NO} | YES | O |  |
| INTRACK\_THRUST | Indication of whether in-track thrust modelling was used for the OD of the object.  Value must be taken from the following list: {YES, NO} | YES | O |  |

## CDM OBJECT1 and OBJECT2 DATA

The CDM Data section shall consist of two separate data blocks (one for “Object1” and the second for “Object2”), each of which will consist of the following logical blocks:

* Physical Parameters;

Covariance shall be specified in the RTN reference frame. Alternate covariance may be specified in either XYZ or the eigenvector decomposition format, as indicated by the ALT\_COV\_TYPE keyword. If ALT\_COV\_TYPE is specified as XYZ, then the reference frame used for the covariance must be specified using the ALT\_COV\_REF\_FRAME parameter.

#### If covariance data for Object1 and Object2 are obtained by interpolation of neighboring relative time points within a covariance matrix time history, such interpolation shall be accomplished by the following process: (1) eigenvalue/vector decomposition; (2) linear (or higher-order) interpolation of neighboring eigenvalues; (3) Euler axis/angle rotation of eigenvectors at intermediate time(s) of interest; (4) linearly-weighted blending of covariances across the bounding timespan of interest, and the resulting (5) recomposition of attained eigenvalues and eigenvectors into covariances at time(s) of interest [H12].  Direct interpolation of covariance matrix components or failure to incorporate sufficient digits of precision on the interpolated covariance elements can produce invalid (non-positive-semidefinite) covariances.

#### The digits of precision provided for orbit and covariance data should be chosen according to best practice to avoid positional and error dispersion loss of precision [H14 and H15], with covariance data being supplied with at least seven significant figures.

The logical blocks of the CDM Data section shall consist of KVN elements as defined in table 3‑5, which specifies for each data item:

1. the keyword to be used;
2. a short description of the item;
3. the units to be used if applicable; and
4. whether the item is mandatory (M), optional (O) or conditional (C). Conditional indicates that the item is mandatory if specified conditions are met (e.g., providing all covariance matrix elements if any are provided).

Table 3‑5 : CDM KVN Data

| **Keyword** | **Description** | **Units** | **MOC** |
| --- | --- | --- | --- |
| COMMENT | (See 6.3.4 for formatting rules.) | n/a | O |
| **OD Parameters** | | | |
| COMMENT | (See 6.3.4 for formatting rules.) | n/a | O |
| TIME\_LASTOB\_START | The start of a time interval (UTC) that contains the time of the last accepted observation. (See 6.3.2.9 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 | O |
| TIME\_LASTOB\_END | The end of a time interval (UTC) that contains the time of the last accepted observation. (See 6.3.2.9 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 | O |
| RECOMMENDED\_OD\_SPAN | The recommended OD time span calculated for the object. Data type = double. | d | O |
| ACTUAL\_OD\_SPAN | Based on the observations available and the RECOMMENDED\_OD\_SPAN, the actual time span used for the OD of the object. Data type = double. | d | O |
| OBS\_AVAILABLE | The number of observations, for the actual time span, available for the OD of the object. Data type = integer. | n/a | O |
| OBS\_USED | The number of observations, for the actual time span, accepted for the OD of the object. Data type = integer. | n/a | O |
| TRACKS\_AVAILABLE | The number of sensor tracks available for the OD of the object. This provides information about the independence of the observational data used in the OD. Data type = integer. | n/a | O |
| TRACKS\_USED | The number of sensor tracks accepted for the OD of the object. This provides information about the independence of the observational data used in the OD. Data type = integer. | n/a | O |
| RESIDUALS\_ACCEPTED | The percentage of residuals accepted in the OD of the object. Data type = double, range = 0.0 to 100.0. | % | O |
| WEIGHTED\_RMS | The weighted Root Mean Square (RMS) of the residuals from a batch least squares OD. (See annex F for definition.) Data type = double. | n/a | O |
| OD\_EPOCH | The epoch of the orbit determination used for this message (UTC). | n/a | O |
| MIN\_MEDIAN\_MAX\_UPDATE\_INTERVAL | For a collection of recent sets of positional knowledge for space objects, the minimum, median, and maximum time between epoch updates for the object in question across the successive sets. An example of such sets is 30 consecutive daily TLEs spanning the last 30 days. Data type = double(3). | d | O |
| **Physical Parameters** | | | |
| COMMENT | (See 6.3.4 for formatting rules.) | n/a | O |
| AREA\_PC | The constant (i.e., non-attitude-dependent) portion of the cross-sectional area of the object used in the calculation of the probability of collision. If AREA\_ALONG\_OEB area values are also supplied, then the total cross-sectional area is calculated as discussed in Annex F. Data type = double. | m\*\*2 | O |
| AREA\_PC\_MIN | Minimum area (or cross-section) of the object to be used in the calculation of the probability of collision. Data type = double. | m\*\*2 | O |
| AREA\_PC\_MAX | Maximum area (or cross-section) of the object to be used in the calculation of the probability of collision. Data type = double. | m\*\*2 | O |
| AREA\_DRG | The effective area of the object exposed to atmospheric drag. Data type = double. | m\*\*2 | O |
| AREA\_SRP | The effective area of the object exposed to solar radiation pressure. Data type = double. | m\*\*2 | O |
| OEB\_PARENT\_FRAME | Parent reference frame which maps to the Optimally Enclosing Box (OEB) frame via the quaternion-based transformation defined in annex F, section F3.  Accepted values are enumerated in the SANA Registry of Orbit-Relative Reference Frames, located at <https://sanaregistry.org/r/orbit_relative_reference_frames/>.  This keyword shall be provided if OEB\_Q1,2,3,C are specified.  Alternatively, a value of “UNKNOWN” can be used to indicate that attitude is tumbling, random, or otherwise unpredictable or unknown. In this case, OEB\_Q1,2,3,C shall not be provided. | n/a | C |
| OEB\_PARENT\_FRAME\_EPOCH | Epoch of the OEB reference frame if not intrinsic to the definition of the reference frame. | n/a | C |
| OEB\_Q1 | q1 = e1 \* sin(φ/2), where φ = Euler rotation angle and e1 = 1st component of Euler rotation axis for the rotation that maps from the OEB\_PARENT\_FRAME (defined above) to the frame aligned with the OEB (defined in annex F, section F3). Data type = double.  If OEB\_PARENT\_FRAME is set to UNKNOWN, then OEB\_Q1 shall not be provided. | n/a | O |
| OEB\_Q2 | q2 = e2 \* sin(φ/2), where φ = Euler rotation angle and e2 = 2nd component of Euler rotation axis for the rotation that maps from the OEB\_PARENT\_FRAME (defined above) to the frame aligned with the OEB (defined in annex F, section F3). Data type = double.  If OEB\_PARENT\_FRAME is set to UNKNOWN, then OEB\_Q2 shall not be provided. | n/a | O |
| OEB\_Q3 | q3 = e3 \* sin(φ/2), where φ = Euler rotation angle and e3 = 3rd component of Euler rotation axis for the rotation that maps from the OEB\_PARENT\_FRAME (defined above) to the frame aligned with the OEB (defined in annex F, section F3). Data type = double.  If OEB\_PARENT\_FRAME is set to UNKNOWN, then OEB\_Q3 shall not be provided. | n/a | O |
| OEB\_QC | qc = cos(φ/2), where φ = Euler rotation angle for the rotation that maps from the OEB\_PARENT\_FRAME (defined above) to the frame aligned with the OEB (defined in annex F, section F3). qc shall be made non-negative by convention, the signs of q1, q2, q3 will all be changed as appropriate to maintain the transformation direction. Data type = double.  If OEB\_PARENT\_FRAME is set to UNKNOWN, then OEB\_QC shall not be provided. | n/a | O |
| OEB\_MAX | Maximum physical dimension of the OEB. Data type = double. | m | O |
| OEB\_INT | Intermediate physical dimension of the OEB. Data type = double. | m | O |
| OEB\_MIN | Minimum physical dimension of the OEB. Data type = double. | m | O |
| AREA\_ALONG\_OEB\_MAX | Cross-sectional area of the object when viewed along maximum OEB direction as defined in annex F, section F3. Data type = double. | m\*\*2 | O |
| AREA\_ALONG\_OEB\_INT | Cross-sectional area of the object when viewed along intermediate OEB direction as defined in annex F, section F3. Data type = double. | m\*\*2 | O |
| AREA\_ALONG\_OEB\_MIN | Cross-sectional area of the object when viewed along minimum OEB direction as defined in annex F, section F3. Data type = double. | m\*\*2 | O |
| RCS | Typical (50th percentile) effective Radar Cross Section of the space object sampled over all possible viewing angles. Data type = double. | m\*\*2 | O |
| RCS\_MIN | Minimum Radar Cross Section observed for this object (Typically 5th percentile). Data type = double. | m\*\*2 | O |
| RCS\_MAX | Maximum Radar Cross Section observed for this object (Typically 95th percentile). Data type = double. | m\*\*2 | O |
| VM\_ABSOLUTE | Typical (50th percentile) absolute Visual Magnitude of the space object sampled over all possible viewing angles and “normalized” as discussed in annex F, section F3, to a 1 Astronomical Unit (AU) Sun-to-target distance, a phase angle of 0° and a 40,000 km target-to-sensor distance (equivalent of GEO satellite tracked at 15.6° above local horizon). Data type = double. | n/a | O |
| VM\_APPARENT\_MIN | Minimum apparent Visual Magnitude observed for this space object (Typically 5th percentile). Data type = double.  NOTE – The ‘MIN’ value represents the dimmest observation, which associates with a higher Vmag. | n/a | O |
| VM\_APPARENT | Typical (50th percentile) apparent Visual Magnitude observed for this space object. Data type = double. | n/a | O |
| VM\_APPARENT\_MAX | Maximum apparent Visual Magnitude observed for this space object (Typically 95th percentile). Data type = double. | n/a | O |
| REFLECTANCE | Typical (50th percentile) coefficient of REFLECTANCE of the space object over all possible viewing angles, ranging from 0 (none) to 1 (perfect reflectance). Data type = double. | n/a | O |
| MASS | The mass of the object. Data type = double. | kg | O |
| HBR | Object hard-body radius, the radius of the sphere used to represent the physical dimensions of this individual space object, for information only. Data type = double. | m | O |
| CD\_AREA\_OVER\_MASS | The object’s *CD•A/m* used to propagate the state vector and covariance to TCA. (See annex F for definition.) Data type = double. | m\*\*2/kg | O |
| CR\_AREA\_OVER\_MASS | The object’s *Cr •A/m* used to propagate the state vector and covariance to TCA. (See annex F for definition.) Data type = double. | m\*\*2/kg | O |
| THRUST\_ACCELERATION | The object’s acceleration due to in-track thrust used to propagate the state vector and covariance to TCA. Data type = double. | m/s\*\*2 | O |
| 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 F for definition.) Data type = double. | W/kg | O |
| MIN\_DV | An array composing of three elements corresponding to the minimum achievable RTN delta-v of the object. Data type = double(3). | m/s | O |
| MAX\_DV | An array composing of three elements corresponding to the maximum achievable RTN delta-v of the object. Data type = double(3). | m/s | O |
| LEAD\_TIME\_REQD\_BEFORE\_TCA | Time required to plan and schedule a maneuver ahead of the predicted TCA. | h | O |
| APOAPSIS\_ALTITUDE | The distance of the furthest point in the object’s orbit above the equatorial radius of the central body about which the object is orbiting. Data type = double. | km | O |
| PERIAPSIS\_ALTITUDE | The distance of the closest point in the object’s orbit above the equatorial radius of the central body about which the object is orbiting. Data type = double. | km | O |
| INCLINATION | The angle between the object’s orbit plane and the orbit center equatorial plane. Data type = double. | deg | O |
| COV\_CONFIDENCE | A measure of the confidence in the covariance errors matching reality, as characterized via a Wald test, a Chi-squared test, the log of likelihood, or a numerical representation per mutual agreement. Data type = double. | n/a | O |
| COV\_CONFIDENCE\_METHOD | A free text field indicating the method used for the calculation of COV\_CONFIDENCE.  (Condition: Mandatory if COV\_CONFIDENCE present) | n/a | C |
| **State Vector (all values have data type=double)** | | | |
| COMMENT | (See 6.3.4 for formatting rules.) | n/a | O |
| X | Object Position Vector X component. | km | M |
| Y | Object Position Vector Y component. | km | M |
| Z | Object Position Vector Z component. | km | M |
| X\_DOT | Object Velocity Vector X component. | km/s | M |
| Y\_DOT | Object Velocity Vector Y component. | km/s | M |
| Z\_DOT | Object Velocity Vector Z component. | km/s | M |
| **Covariance Matrix in the RTN Coordinate Frame** (see annex F for RTN frame 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 | O |
| CR\_R | Object covariance matrix [1,1]. | m\*\*2 | M |
| CT\_R | Object covariance matrix [2,1]. | m\*\*2 | M |
| CT\_T | Object covariance matrix [2,2]. | m\*\*2 | M |
| CN\_R | Object covariance matrix [3,1]. | m\*\*2 | M |
| CN\_T | Object covariance matrix [3,2]. | m\*\*2 | M |
| CN\_N | Object covariance matrix [3,3]. | m\*\*2 | M |
| CRDOT\_R | Object covariance matrix [4,1]. | m\*\*2/s | M |
| CRDOT\_T | Object covariance matrix [4,2]. | m\*\*2/s | M |
| CRDOT\_N | Object covariance matrix [4,3]. | m\*\*2/s | M |
| CRDOT\_RDOT | Object covariance matrix [4,4]. | m\*\*2/s\*\*2 | M |
| CTDOT\_R | Object covariance matrix [5,1]. | m\*\*2/s | M |
| CTDOT\_T | Object covariance matrix [5,2]. | m\*\*2/s | M |
| CTDOT\_N | Object covariance matrix [5,3]. | m\*\*2/s | M |
| CTDOT\_RDOT | Object covariance matrix [5,4]. | m\*\*2/s\*\*2 | M |
| CTDOT\_TDOT | Object covariance matrix [5,5]. | m\*\*2/s\*\*2 | M |
| CNDOT\_R | Object covariance matrix [6,1]. | m\*\*2/s | M |
| CNDOT\_T | Object covariance matrix [6,2]. | m\*\*2/s | M |
| CNDOT\_N | Object covariance matrix [6,3]. | m\*\*2/s | M |
| CNDOT\_RDOT | Object covariance matrix [6,4]. | m\*\*2/s\*\*2 | M |
| CNDOT\_TDOT | Object covariance matrix [6,5]. | m\*\*2/s\*\*2 | M |
| CNDOT\_NDOT | Object covariance matrix [6,6]. | m\*\*2/s\*\*2 | M |
| CDRG\_R | Object covariance matrix [7,1]. | m\*\*3/kg | O |
| CDRG\_T | Object covariance matrix [7,2]. | m\*\*3/kg | O |
| CDRG\_N | Object covariance matrix [7,3]. | m\*\*3/kg | O |
| CDRG\_RDOT | Object covariance matrix [7,4]. | m\*\*3/(kg\*s) | O |
| CDRG\_TDOT | Object covariance matrix [7,5]. | m\*\*3/(kg\*s) | O |
| CDRG\_NDOT | Object covariance matrix [7,6]. | m\*\*3/(kg\*s) | O |
| CDRG\_DRG | Object covariance matrix [7,7]. | m\*\*4/kg\*\*2 | O |
| CSRP\_R | Object covariance matrix [8,1]. | m\*\*3/kg | O |
| CSRP\_T | Object covariance matrix [8,2]. | m\*\*3/kg | O |
| CSRP\_N | Object covariance matrix [8,3]. | m\*\*3/kg | O |
| CSRP\_RDOT | Object covariance matrix [8,4]. | m\*\*3/(kg\*s) | O |
| CSRP\_TDOT | Object covariance matrix [8,5]. | m\*\*3/(kg\*s) | O |
| CSRP\_NDOT | Object covariance matrix [8,6]. | m\*\*3/(kg\*s) | O |
| CSRP\_DRG | Object covariance matrix [8,7]. | m\*\*4/kg\*\*2 | O |
| CSRP\_SRP | Object covariance matrix [8,8]. | m\*\*4/kg\*\*2 | O |
| CTHR\_R | Object covariance matrix [9,1]. | m\*\*2/s\*\*2 | O |
| CTHR\_T | Object covariance matrix [9,2]. | m\*\*2/s\*\*2 | O |
| CTHR\_N | Object covariance matrix [9,3]. | m\*\*2/s\*\*2 | O |
| CTHR\_RDOT | Object covariance matrix [9,4]. | m\*\*2/s\*\*3 | O |
| CTHR\_TDOT | Object covariance matrix [9,5]. | m\*\*2/s\*\*3 | O |
| CTHR\_NDOT | Object covariance matrix [9,6]. | m\*\*2/s\*\*3 | O |
| CTHR\_DRG | Object covariance matrix [9,7]. | m\*\*3/(kg\*s\*\*2) | O |
| CTHR\_SRP | Object covariance matrix [9,8]. | m\*\*3/(kg\*s\*\*2) | O |
| CTHR\_THR | Object covariance matrix [9,9]. | m\*\*2/s\*\*4 | O |
| **Covariance Matrix in the XYZ Coordinate Frame** (defined by value of ALT\_COV\_REF\_FRAME)  (Covariance Matrix 9×9 Lower Triangular Form. All parameters of the 6×6 position/velocity submatrix must be given. All data type=double.)  **Conditional on ALT\_COV\_TYPE = XYZ** | | | |
| COMMENT | (See 6.3.4 for formatting rules.) | n/a | O |
| CX\_X | Object covariance matrix [1,1]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2 | C |
| CY\_X | Object covariance matrix [2,1]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2 | C |
| CY\_Y | Object covariance matrix [2,2].(Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2 | C |
| CZ\_X | Object covariance matrix [3,1]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2 | C |
| CZ\_Y | Object covariance matrix [3,2]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2 | C |
| CZ\_Z | Object covariance matrix [3,3]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2 | C |
| CXDOT\_X | Object covariance matrix [4,1]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s | C |
| CXDOT\_Y | Object covariance matrix [4,2]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s | C |
| CXDOT\_Z | Object covariance matrix [4,3]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s | C |
| CXDOT\_XDOT | Object covariance matrix [4,4]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*2 | C |
| CYDOT\_X | Object covariance matrix [5,1]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s | C |
| CYDOT\_Y | Object covariance matrix [5,2]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s | C |
| CYDOT\_Z | Object covariance matrix [5,3]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s | C |
| CYDOT\_XDOT | Object covariance matrix [5,4]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*2 | C |
| CYDOT\_YDOT | Object covariance matrix [5,5]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*2 | C |
| CZDOT\_X | Object covariance matrix [6,1]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s | C |
| CZDOT\_Y | Object covariance matrix [6,2]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s | C |
| CZDOT\_Z | Object covariance matrix [6,3]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s | C |
| CZDOT\_XDOT | Object covariance matrix [6,4]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*2 | C |
| CZDOT\_YDOT | Object covariance matrix [6,5]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*2 | C |
| CZDOT\_ZDOT | Object covariance matrix [6,6]. (Condition: Mandatory if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*2 | C |
| CDRG\_X | Object covariance matrix [7,1]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/kg | C |
| CDRG\_Y | Object covariance matrix [7,2]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/kg | C |
| CDRG\_Z | Object covariance matrix [7,3]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/kg | C |
| CDRG\_XDOT | Object covariance matrix [7,4]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/(kg\*s) | C |
| CDRG\_YDOT | Object covariance matrix [7,5]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/(kg\*s) | C |
| CDRG\_ZDOT | Object covariance matrix [7,6]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/(kg\*s) | C |
| CDRG\_DRG | Object covariance matrix [7,7]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*4/kg\*\*2 | C |
| CSRP\_X | Object covariance matrix [8,1]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/kg | C |
| CSRP\_Y | Object covariance matrix [8,2]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/kg | C |
| CSRP\_Z | Object covariance matrix [8,3]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/kg | C |
| CSRP\_XDOT | Object covariance matrix [8,4]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/(kg\*s) | C |
| CSRP\_YDOT | Object covariance matrix [8,5]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/(kg\*s) | C |
| CSRP\_ZDOT | Object covariance matrix [8,6]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/(kg\*s) | C |
| CSRP\_DRG | Object covariance matrix [8,7]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*4/kg\*\*2 | C |
| CSRP\_SRP | Object covariance matrix [8,8]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*4/kg\*\*2 | C |
| CTHR\_X | Object covariance matrix [9,1]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*2 | C |
| CTHR\_Y | Object covariance matrix [9,2]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*2 | C |
| CTHR\_Z | Object covariance matrix [9,3]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*2 | C |
| CTHR\_XDOT | Object covariance matrix [9,4]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*3 | C |
| CTHR\_YDOT | Object covariance matrix [9,5]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*3 | C |
| CTHR\_ZDOT | Object covariance matrix [9,6]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*3 | C |
| CTHR\_DRG | Object covariance matrix [9,7]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/(kg\*s\*\*2) | C |
| CTHR\_SRP | Object covariance matrix [9,8]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*3/(kg\*s\*\*2) | C |
| CTHR\_THR | Object covariance matrix [9,9]. (Condition: Optional if ALT\_COV\_TYPE = XYZ) | m\*\*2/s\*\*4 | C |
| **Covariance Matrix in Sigmas/Eigenvector format**  (Covariance sigmas and eigenvectors for major, intermediate and minor eigenvalues and associated eigenvectors. All data type=double.)  **Conditional on ALT\_COV\_TYPE = CSIG3EIGVEC3** | | | |
| COMMENT | (See 6.3.4 for formatting rules.) | n/a | C |
| CSIG3EIGVEC3 | The positional covariance one-sigma dispersions corresponding to the major, intermediate, and minor eigenvalues, followed by the associated eigenvectors, shall all be presented on a single line (12 values separated by spaces). (Condition: Mandatory if ALT\_COV\_TYPE = CSIG3EIGVEC3) | n/a | C |
| **Additional covariance metadata (Optional)** | | | |
| COMMENT | (See 6.3.4 for formatting rules.) | n/a | O |
| DENSITY\_FORECAST\_UNCERTAINTY | The atmospheric density forecast error is a compensation factor that is added to the drag variance in the covariance matrix to reflect expected errors in predicting the future atmospheric density. Data type = double. | n/a | O |
| CSCALE\_FACTOR\_MIN | The minimum suggested covariance scale factor, used to improve covariance realism by scaling the eigenvalues corresponding to the covariance for this object. A scale factor of one denotes a “realistic” covariance that fairly represents the actual error distribution. Data type = double.  NOTE 1 – The supplied one-sigma deviations get multiplied by CSCALE\_FACTOR\_MIN, while the covariance matrix must be multiplied by CSCALE\_FACTOR\_MIN2 to scale the covariance appropriately as shown in Annex F.  NOTE 2 – If COLLISION\_MAX\_PC\_METHOD = SCALE\_COMBINED\_COVAR, this scale factor is used when included with OBJECT1, and disregarded when included with OBJECT2. | n/a | O |
| CSCALE\_FACTOR | The suggested (median) covariance scale factor, used to improve covariance realism by scaling the eigenvalues corresponding to the covariance for this object. A scale factor of one denotes a “realistic” covariance that fairly represents the actual error distribution. Data type = double.  NOTE 1 – The supplied one-sigma deviations get multiplied by CSCALE\_FACTOR, while the covariance matrix must be multiplied by CSCALE\_FACTOR2 to scale the covariance appropriately as shown in Annex F.  NOTE 2 – If COLLISION\_MAX\_PC\_METHOD = SCALE\_COMBINED\_COVAR, this scale factor is used when included with OBJECT1, and disregarded when included with OBJECT2. | n/a | O |
| CSCALE\_FACTOR\_MAX | The maximum suggested covariance scale factor, used to improve covariance realism by scaling the eigenvalues corresponding to the covariance for this object. A scale factor of one denotes a “realistic” covariance that fairly represents the actual error distribution. Data type = double.  NOTE 1 – The supplied one-sigma deviations get multiplied by, CSCALE\_FACTOR\_MAX while the covariance matrix must be multiplied by CSCALE\_FACTOR\_MAX2 to scale the covariance appropriately as shown in Annex F.  NOTE 2 – If COLLISION\_MAX\_PC\_METHOD = SCALE\_COMBINED\_COVAR, this scale factor is used when included with OBJECT1, and disregarded when included with OBJECT2. | n/a | O |
| SCREENING\_DATA\_SOURCE | Free-text string specifying the source (or origin) of the specific orbital data for this object that was used in the screening. | n/a | O |
| DCP\_SENSITIVITY\_VECTOR\_POSITION | The drag consider parameter (DCP) sensitivity vectors map forward expected error in the drag acceleration to actual componentized position errors at TCA. Data type = double(3). See Annex F4 and reference [H19] for more information. | m | O |
| DCP\_SENSITIVITY\_VECTOR\_VELOCITY | The drag consider parameter (DCP) sensitivity vectors map forward expected error in the drag acceleration to actual componentized velocity errors at TCA. Data type = double(3). See Annex F4 and reference [H19] for more information. | m/s | O |

## CDM USER-DEFINED PARAMETERS

A section of user-defined parameters may be provided if necessary. In principle, this provides flexibility, but also introduces complexity, non-standardisation, potential ambiguity, and potential processing errors. Accordingly, if used, the keywords and their meanings must be described in an Interface Control Document (ICD). The use of User-Defined Parameters is not encouraged. The user-defined parameters shall consist of the KVN elements defined in table 3‑6, which specifies for each KVN metadata item:

1. the keyword to be used;
2. a short description of the item;
3. the units to be used if applicable;
4. examples of allowed values;

Table 3‑6 : CDM KVN User-Defined Parameters

| **Keyword** | **Description** | **Units** | **Examples** |
| --- | --- | --- | --- |
| COMMENT | (See 6.3.4 for formatting rules.) | n/a | COMMENT This is a comment |
| USER\_DEFINED\_x | User-defined parameter where ‘x’ is replaced by a variable length user specified character string. Any number of user defined parameters may be included if necessary to provide essential information that cannot be conveyed in standard CDM keywords. |  | USER\_DEFINED\_OBJ1\_MAX\_MNVR\_PER\_HOUR=2 |



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# CDM CONTENT/STRUCTURE IN XML

## 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:

<https://nav.sanaregistry.org/r/ndmxml_unqualified/ndmxml-5.0.0-cdm-2.0.xsd> for messages with elements not qualified with respect to a namespace.

<https://nav.sanaregistry.org/r/ndmxml_qualified/ndmxml-5.0.0-cdm-2.0.xsd> for messages with elements qualified with respect to a namespace. (For more information regarding messages with elements qualified with respect to a namespace, see [6] Section 4.3.)

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:

<https://nav.sanaregistry.org/r/ndmxml_unqualified/ndmxml-5.0.0-cdm-2.0.xsl> for messages with elements not qualified with respect to a namespace.

<https://nav.sanaregistry.org/r/ndmxml_qualified/ndmxml-5.0.0-cdm-2.0.xsl> for messages with elements qualified with respect to a namespace.

## CDM/XML BASIC STRUCTURE

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

The CDM body shall consist of one relative metadata/data and two segment constructs.

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

XML tags shall be uppercase and correspond with the KVN keywords in 3.2 through 3.6 (uppercase with ‘\_’ [the underscore character] as separators). The XML logical tags related to message structure shall be in lowerCamelCase.

## CONSTRUCTING A CDM/XML INSTANCE

### OVERVIEW

This subsection provides more detailed instructions for the user on how to create an XML message based on the ASCII-text KVN-formatted message described in Sections 3.1 through 3.6.

### 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.

### BEGINNING THE INSTANTIATION: root Data element

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

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"

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 in the instantiation.

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.

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

xsi:noNamespaceSchemaLocation="<https://nav.sanaregistry.org/r/ndmxml_unqualified/ndmxml-5.0.0-master-4.0.xsd>" for messages with elements not qualified with respect to a namespace.

xsi:noNamespaceSchemaLocation="<https://nav.sanaregistry.org/r/ndmxml_qualified/ndmxml-5.0.0-master-4.0.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.

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.

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

The final attributes of the <cdm> tag shall be ‘id’ and ‘version’.

The ‘id’ attribute shall be ‘id="CCSDS\_CDM\_VERS"’.

The ‘version’ attribute shall be ‘version="2.0"’.

NOTE – 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://nav.sanaregistry.org/r/ndmxml_unqualified/ndmxml-5.0.0-master-4.0.xsd>" id="CCSDS\_CDM\_VERS" version="2.0">

NOTE – 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://nav.sanaregistry.org/r/ndmxml_qualified/ndmxml-5.0.0-master-4.0.xsd>" id="CCSDS\_CDM\_VERS" version="2.0"

### THE CDM/XML HEADER SECTION

The CDM header shall have a standard header format, with tags <header> and </header>.

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

The standard CDM header shall contain the following element tags:

1. optional <CLASSIFICATION>.
2. <CREATION\_DATE>;
3. <ORIGINATOR>;
4. optional <MESSAGE\_FOR>;
5. <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>

<CLASSIFICATION>UNCLASSIFIED</CLASSIFICATION>

<CREATION\_DATE>2010-03-12T22:31:12.000</CREATION\_DATE>

<ORIGINATOR> CSPOC </ORIGINATOR>

<MESSAGE\_FOR>SATELLITE A</MESSAGE\_FOR>

<MESSAGE\_ID>201113719185</MESSAGE\_ID>

</header>

### THE CDM/XML BODY SECTION

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

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

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

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

### THE CDM/XML RELATIVE METADATA/DATA SECTION

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

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

Between the <relativeMetadataData> and </relativeMetadataData> tags, the keywords shall be those specified in table 3‑3.

### THE CDM/XML METADATA SECTION

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

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.

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

Between the <metadata> and </metadata> tags for both Object1 and Object2, the keywords shall be those specified in table 3‑4. The value of the keyword OBJECT shall be used to define whether the metadata defines Object1 or Object2.

### THE CDM DATA SECTION

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

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

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

Between the <data> and </data> tags, the keywords shall be those specified in table 3‑5. The value of the keyword OBJECT, referenced in table 3‑4, shall be used to define whether the data defines Object1 or Object2.

### SPECIAL CDM/XML TAGS

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.

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> |
| **Physical Parameters** | <physicalParameters> |
| **State Vector** | <stateVector> |
| **Covariance Matrix in RTN** | <covarianceMatrixRTN> |
| **Covariance Matric in XYZ** | <covarianceMatrixXYZ> |
| **Covariance Matrix SIG3EIGVEC3** | <covarianceMatrixSig3Eigvec3> |
| **Additional Covariance Data** | <additionalCovariance> |
| **User Defined Parameters** | <userDefinedParameters> |

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. |

### 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).







CDM/XML examples are provided at annex G, section G2.

# CDM DATA IN GENERAL

## Overview

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

## Rules that apply in KVN and XML

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

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.

Table 3‑5 is broken into seven 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.

For *CD•A/m*, CD\_AREA\_OVER\_MASS, a value of zero shall indicate no atmospheric drag was modelled in the orbit determination process.

For *CR•A/m*, CR\_AREA\_OVER\_MASS, a value of zero shall indicate no solar radiation pressure was modelled in the orbit determination process.

Foracceleration due to in-track thrust, THRUST\_ACCELERATION, a value of zero shall indicate no in-track thrust acceleration was modelled in the orbit determination process.

For this specification, covariance information shall be provided. The object covariance may be specified as either a lower triangular matrix or in Eigenvalue/Eigenvector format:

* Lower Triangular Format: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 6.3.2.5.   
    
  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).
* Sigma/Eigenvector Format: This format comprises the one-sigma dispersions of the combined error covariance matrix along the major, intermediate, and minor eigenvector directions, followed by the associated major, intermediate, and minor eigenvectors, provided as a single line of twelve white space-delimited quantities.

For covariance matrix type, a lower triangular RTN formatted covariance shall be mandatory. If ALT\_COV\_TYPE is specified and has a value of XYZ, ALT\_COV\_REF\_FRAME shall be mandatory specifying the reference frame of the mandatory lower triangular XYZ formatted covariance.

For vector types, all components shall be supplied.

# CDM SYNTAX

## OVERVIEW

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

## Common CDM Syntax

### Overview

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

### Common CDM Lines

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

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.

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

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.

### Common CDM Values

#### A nonempty, valid value must be specified for each mandatory keyword.

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

All time tags in the CDM shall be in UTC.

### Common CDM Units

If units are applicable, as specified in table 3‑3 and/or table 3‑5, 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.)

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).

### Common CDM Comments

#### For the CDM, comment lines shall be optional.

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.

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

## The CDM in KVN

### CDM Lines in KVN

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.

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

All header, relative metadata/data, metadata, and data lines shall use ‘keyword = value’ notation. For this purpose, only those keywords shown in table 3‑2, table 3‑3, table 3‑4, and table 3‑5 shall be used in a CDM.

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

Keywords must be uppercase and must not contain blanks.

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

Any white space immediately preceding or following the ‘equals’ sign shall not be significant.

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

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

### CDM Values in KVN

Comments and free-text value fields may be in any case (or mix of upper and lower case) desired by the user.

Apart from comments and free-text fields, normative text value fields shall be constructed using only exclusively all uppercase or exclusively all lowercase.

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

-2,147,483,648 ≤ x ≤ +2,147,483,647 (i.e., -231 ≤ x ≤ 231-1, a 4-byte integer)

or -9,223,372,036,854,775,808 <= x <= +9,223,372,036,854,775,807 (i.e., -263 ≤ x ≤ 263-1, an 8 byte integer).

NOTE – The commas in the range of values above are thousands separators and are used only for readability. They are not included in the integer representation in the actual message.

Non-integer numeric values may be expressed in either fixed-point or floating-point notation. Both representations may be used within a CDM.

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.

Non-integer numeric values expressed in floating-point notation shall conform to the IEEE binary64 floating point number format (see reference [8]). Such numbers consist of an optional sign, a mantissa, an alphabetic character separating the mantissa from the exponent, and an exponent, constructed according to the following rules:

1. The sign may be ‘+’ or ‘-’. If the sign is omitted, ‘+’ shall be assumed.
2. The mantissa must be a string of no more than 16 decimal digits with a decimal point (‘.’) in the second position of the ASCII string, separating the integer portion of the mantissa from the fractional part of the mantissa.
3. The character used to denote exponentiation shall be ‘E’ or ‘e’.
4. The exponent must be an integer and may have either a ‘+’ or ‘-’ sign (if the sign is omitted, then ‘+’ shall be assumed). Exponent values can range from -324 to +308.
5. The maximum positive floating-point value is approximately 1.798E+308, with 16 significant decimal digits precision. The minimum positive floating-point value is approximately 4.941E-324, with 16 significant decimal digits precision.

For all numeric values, exchange participants may agree to further constrain or even extend beyond the default limit of 16 digits of precision.

Blanks shall not be used within numeric values.

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.

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.)

### CDM Units in KVN

When units are displayed, then:

1. there must be at least one blank character between the value and the units;
2. the units must be enclosed within square brackets (e.g., ‘[km]’).

### 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.

## The CDM in XML

### CDM Lines in XML

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.

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

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.

### CDM Values in XML

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.

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.

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.

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 6.3.2.9.

### 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> |

### CDM Comments in XML

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

1. Implementation Conformance Statement (ICS) Proforma  
     
   (Normative)
   1. Introduction
      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.
  + 1. Abbreviations and Conventions

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

Item Column

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.

C conditional.

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.

* + 1. 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.

* 1. ICS Proforma for Conjunction Data Message
     1. General Information
        1. Identification of ICS

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

* + - 1. Identification of Implementation Under Test (IUT)

|  |  |
| --- | --- |
| Implementation name |  |
| Implementation version |  |
| Special Configuration |  |
| Other Information |  |

* + - 1. 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) |  |

* + - 1. Document Version

|  |  |
| --- | --- |
| CCSDS 508.0-B-2 |  |
| 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\_\_\_\_\_ |

* + - 1. Requirements List

| **Item** | **Feature** | **Keyword** | **Reference** | **Status** | **Support** |
| --- | --- | --- | --- | --- | --- |
|  | CDM Header | N/A | Table 3‑2 | M |  |
|  | CDM version | CCSDS\_CDM\_VERS | Table 3‑2 | M |  |
|  | Comment | COMMENT | Table 3‑2 | O |  |
|  | Classification | CLASSIFICATION | Table 3‑2 | O |  |
|  | Message creation date/time | CREATION\_DATE | Table 3‑2 | M |  |
|  | Message originator | ORIGINATOR | Table 3‑2 | M |  |
|  | Spacecraft name(s) | MESSAGE\_FOR | Table 3‑2 | O |  |
|  |  | MESSAGE\_ID | Table 3‑2 | M |  |
|  |  | N/A | Table 3‑3 | M |  |
|  |  | COMMENT | Table 3‑3 | O |  |
|  | Unique conjunction identifier | CONJUNCTION\_ID | Table 3‑3 | O |  |
|  |  | TCA | Table 3‑3 | M |  |
|  |  | MISS\_DISTANCE | Table 3‑3 | M |  |
|  | Mahalanobis distance at TCA | MAHALANOBIS\_DISTANCE | Table 3‑3 | O |  |
|  |  | RELATIVE\_SPEED | Table 3‑3 | O |  |
|  | Relative position of Object2 with respect to Object1 | RELATIVE\_POSITION\_R,  RELATIVE\_POSITION\_T,  RELATIVE\_POSITION\_N | Table 3‑3 | O |  |
|  | Relative velocity of Object2 with respect to Object1 | RELATIVE\_VELOCITY\_R, RELATIVE\_VELOCITY\_T,  RELATIVE\_VELOCITY\_N | Table 3‑3 | O |  |
|  | The approach angle between Object1 and Object2 | APPROACH\_ANGLE | Table 3‑3 | O |  |
|  |  | START\_SCREEN\_PERIOD,  STOP\_SCREEN\_PERIOD | Table 3‑3 | O |  |
|  | Object1 centered screening type | SCREEN\_TYPE | Table 3‑3 | O |  |
|  |  | SCREEN\_VOLUME\_SHAPE  SCREEN\_VOLUME\_RADIUS  SCREEN\_VOLUME\_X,  SCREEN\_VOLUME\_Y,  SCREEN\_VOLUME\_Z | Table 3‑3 | C |  |
|  | Screening volume entry/exit times for Object2 | SCREEN\_ENTRY\_TIME,  SCREEN\_EXIT\_TIME | Table 3‑3 | C |  |
|  | Collision probability screening threshold | SCREEN\_PC\_THRESHOLD | Table 3‑3 | C |  |
|  | Probability Cumulative Distribution Function (CDF) that Object1 and Object2 will collide | COLLISION\_PERCENTILE  COLLISION\_PROBABILITY | Table 3‑3 | O |  |
|  |  | COLLISION\_PROBABILITY\_METHOD | Table 3‑3 | O |  |
|  | Collision maximum probability parameters | COLLISION\_MAX\_PROBABILITY  COLLISION\_MAX\_PC\_METHOD | Table 3‑3 | O |  |
|  | Space environment fragmentation impact adjusted collision probability | SEFI\_COLLISION\_PROBABILITY | Table 3‑3 | O |  |
|  | Method that was used to calculate the SEFI collision probability | SEFI\_COLLISION\_PROBABILITY\_METHOD | Table 3‑3 | O |  |
|  | Space environment fragmentation model. | SEFI\_FRAGMENTATION\_MODEL | Table 3‑3 | O |  |
|  | Message Information | N/A | Table 3‑3 | O |  |
|  | Previous message ID | PREVIOUS\_MESSAGE\_ID | Table 3‑3 | O |  |
|  | Previous message epoch | PREVIOUS\_MESSAGE\_EPOCH | Table 3‑3 | O |  |
|  | Next message epoch | NEXT\_MESSAGE\_EPOCH | Table 3‑3 | O |  |
|  | CDM Metadata | N/A | Table 3‑4 | M |  |
|  |  | COMMENT | Table 3‑4 | O |  |
|  |  | OBJECT | Table 3‑4 | M |  |
|  |  | OBJECT\_DESIGNATOR | Table 3‑4 | M |  |
|  |  | CATALOG\_NAME | Table 3‑4 | M |  |
|  | Spacecraft name for the object | OBJECT\_NAME | Table 3‑4 | M |  |
|  |  | INTERNATIONAL\_DESIGNATOR | Table 3‑4 | M |  |
|  | Type of space object | OBJECT\_TYPE | Table 3‑4 | O |  |
|  | Operational status of object | OPS\_STATUS | Table 3‑4 | O |  |
|  |  | OPERATOR\_CONTACT\_POSITION,  OPERATOR\_ORGANIZATION,  OPERATOR\_PHONE,  OPERATOR\_EMAIL | Table 3‑4 | O |  |
|  |  | EPHEMERIS\_NAME | Table 3‑4 | M |  |
|  | Link to external ODM | ODM\_MSG\_LINK | Table 3‑4 | C |  |
|  | Link to external ADM | ADM\_MSG\_LINK | Table 3‑4 | O |  |
|  | Observations scheduled before next message | OBS\_BEFORE\_NEXT\_MESSAGE | Table 3‑4 | O |  |
|  |  | COVARIANCE\_METHOD | Table 3‑4 | M |  |
|  | Covariance source | COVARIANCE\_SOURCE | Table 3‑4 | O |  |
|  |  | MANEUVERABLE | Table 3‑4 | M |  |
|  |  |  | Table 3‑4 | O |  |
|  |  | REF\_FRAME | Table 3‑4 | M |  |
|  | Type of alternate covariance information provided | ALT\_COV\_TYPE | Table 3‑4 | O |  |
|  | Alternate covariance reference frame if covariance provided in XYZ format (Conditional on ALT\_COV\_TYPE) | ALT\_COV\_REF\_FRAME | Table 3‑4 | C |  |
|  | Gravity model used for OD |  | Table 3‑4 | O |  |
|  |  | ATMOSPHERIC\_MODEL | Table 3‑4 | O |  |
|  | N-body gravitational perturbations used for OD | N\_BODY\_PERTURBATIONS | Table 3‑4 | O |  |
|  |  | SOLAR\_RAD\_PRESSURE | Table 3‑4 | O |  |
|  |  | EARTH\_TIDES | Table 3‑4 | O |  |
|  |  | INTRACK\_THRUST | Table 3‑4 | O |  |
|  | CDM Data | N/A | Table 3‑5 | M |  |
|  |  | COMMENT | Table 3‑5 | O |  |
|  |  | N/A | Table 3‑5 | O |  |
|  | Comment | COMMENT | Table 3‑5 | O |  |
|  |  | TIME\_LASTOB\_START,  TIME\_LASTOB\_END | Table 3‑5 | O |  |
|  | Recommended/actual OD time span for object | RECOMMENDED\_OD\_SPAN,  ACTUAL\_OD\_SPAN | Table 3‑5 | O |  |
|  |  | OBS\_AVAILABLE,  OBS\_USED | Table 3‑5 | O |  |
|  |  | TRACKS\_AVAILABLE,  TRACKS\_USED | Table 3‑5 | O |  |
|  |  | RESIDUALS\_ACCEPTED | Table 3‑5 | O |  |
|  |  | WEIGHTED\_RMS | Table 3‑5 | O |  |
|  | Epoch of the orbit determination | OD\_EPOCH | Table 3‑5 | O |  |
|  | Minimum, median and maximum update interval for orbital information | MIN\_MEDIAN\_MAX\_UPDATE\_INTERVAL | Table 3‑5 | O |  |
|  | PhysicalParameters | N/A | Table 3‑5 | O |  |
|  |  | COMMENT | Table 3‑5 | O |  |
|  |  | AREA\_PC | Table 3‑5 | O |  |
|  | Minimum area of the object | AREA\_PC\_MIN | Table 3‑5 | O |  |
|  | Maximum area of the object | AREA\_PC\_MAX | Table 3‑5 | O |  |
|  |  | AREA\_DRG | Table 3‑5 | O |  |
|  |  | AREA\_SRP | Table 3‑5 | O |  |
|  | Reference frame for OEB | OEB\_PARENT\_FRAME | Table 3‑5 | O |  |
|  | Epoch of OEB reference frame | OEB\_PARENT\_FRAME\_EPOCH | Table 3‑5 | O |  |
|  | Euler rotation for OEB | OEB\_Q1 | Table 3‑5 | O |  |
|  | Euler rotation for OEB | OEB\_Q2 | Table 3‑5 | O |  |
|  | Euler rotation for OEB | OEB\_Q3 | Table 3‑5 | O |  |
|  | Euler rotation for OEB | OEB\_QC | Table 3‑5 | O |  |
|  | Maximum dimension of OEB | OEB\_MAX | Table 3‑5 | O |  |
|  | Intermediate dimension of OEB | OEB\_INT | Table 3‑5 | O |  |
|  | Minimum dimension of OEB | OEB\_MIN | Table 3‑5 | O |  |
|  | Area along maximum OEB | AREA\_ALONG\_OEB\_MAX | Table 3‑5 | O |  |
|  | Area along Intermediate OEB | AREA\_ALONG\_OEB\_INT | Table 3‑5 | O |  |
|  | Area along minimum OEB | AREA\_ALONG\_OEB\_MIN | Table 3‑5 | O |  |
|  | Typical radar cross-sectional area | RCS | Table 3‑5 | O |  |
|  | Min radar cross-sectional area | RCS\_MIN | Table 3‑5 | O |  |
|  | Max radar cross-sectional area | RCS\_MAX | Table 3‑5 | O |  |
|  | Typical absolute visual magnitude | VM\_ABSOLUTE | Table 3‑5 | O |  |
|  | Min apparent visual magnitude | VM\_APPARENT\_MIN | Table 3‑5 | O |  |
|  | Apparent visual magnitude | VM\_APPARENT | Table 3‑5 | O |  |
|  | Max apparent visual magnitude | VM\_APPARENT\_MAX | Table 3‑5 | O |  |
|  | Typical surface reflectance | REFLECTANCE | Table 3‑5 | O |  |
|  |  | MASS | Table 3‑5 | O |  |
|  | Hard-body radius | HBR | Table 3‑5 | O |  |
|  | Object’s CD•A/m and CR•A/m used to propagate state vector and covariance to TCA | CD\_AREA\_OVER\_MASS,  CR\_AREA\_OVER\_MASS | Table 3‑5 | O |  |
|  |  | THRUST\_ACCELERATION | Table 3‑5 | O |  |
|  |  | SEDR | Table 3‑5 | O |  |
|  | RTN array of minimum achievable delta-v | MIN\_DV | Table 3‑5 | O |  |
|  | RTN array of maximum achievable delta-v | MAX\_DV | Table 3‑5 | O |  |
|  | Time required to plan and schedule a maneuver ahead of the predicted TCA | LEAD\_TIME\_REQD\_BEFORE\_TCA | Table 3‑5 | O |  |
|  | Object’s apoapsis height above the central body which it is orbiting | APOAPSIS\_ALTITUDE | Table 3‑5 | O |  |
|  | Object’s periapsis height above the central body which it is orbiting | PERIAPSIS\_ALTITUDE | Table 3‑5 | O |  |
|  | Angle between objects orbit plane and body equatorial plane | INCLINATION | Table 3‑5 | O |  |
|  | Covariance confidence | COV\_CONFIDENCE | Table 3‑5 | O |  |
|  | Method used to calculate COV\_CONFIDENCE  (COV\_CONFIDENCE present) | COV\_CONFIDENCE\_METHOD | Table 3‑5 | C |  |
|  | State Vector | N/A | Table 3‑5 | M |  |
|  |  | COMMENT | Table 3‑5 | O |  |
|  | Object Position Vector | X, Y, Z | Table 3‑5 | M |  |
|  |  | X\_DOT, Y\_DOT, Z\_DOT | Table 3‑5 | M |  |
|  | Covariance Matrix in the RTN Coordinate Frame | N/A | Table 3‑5 | M |  |
|  |  | COMMENT | Table 3‑5 | O |  |
|  | 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 3‑5 | M |  |
|  |  | CDRG\_R, CDRG\_T, CDRG\_N,  CDRG\_RDOT, CDRG\_TDOT,  CDRG\_NDOT, CDRG\_DRG | Table 3‑5 | O |  |
|  |  | CSRP\_R, CSRP\_T, CSRP\_N,  CSRP\_RDOT, CSRP\_TDOT,  CSRP\_NDOT, CSRP\_DRG,  CSRP\_SRP | Table 3‑5 | O |  |
|  |  | CTHR\_R, CTHR\_T, CTHR\_N,  CTHR\_RDOT, CTHR\_TDOT,  CTHR\_NDOT, CTHR\_DRG,  CTHR\_SRP, CTHR\_THR | Table 3‑5 | O |  |
|  | Covariance Matrix (ALT\_COV\_TYPE = XYZ) | N/A | Table 3‑5 | C |  |
|  | Comment  (ALT\_COV\_TYPE = XYZ) | COMMENT | Table 3‑5 | C |  |
|  | Position/velocity 6×6 covariance matrix  (ALT\_COV\_TYPE = XYZ) | CX\_X, CY\_X, CY\_Y, CZ\_X, CZ\_Y, CZ\_Z, CXDOT\_X, CXDOT\_Y, CXDOT\_Z, CXDOT\_XDOT, CYDOT\_X, CYDOT\_Y, CYDOT\_Z,  CYDOT\_XDOT, CYDOT\_YDOT, CZDOT\_X, CZDOT\_Y, CZDOT\_Z,  CZDOT\_XDOT, CZDOT\_YDOT, CZDOT\_ZDOT | Table 3‑5 | C |  |
|  | Covariance matrix row 7 (Drag related)  (ALT\_COV\_TYPE = XYZ) | CDRG\_X, CDRG\_Y, CDRG\_Z,  CDRG\_XDOT, CDRG\_YDOT,  CDRG\_ZDOT, CDRG\_DRG | Table 3‑5 | C |  |
|  | Covariance matrix row 8 (Solar Radiation Pressure related)  (ALT\_COV\_TYPE = XYZ) | CSRP\_X, CSRP\_Y, CSRP\_Z,  CSRP\_XDOT, CSRP\_YDOT,  CSRP\_ZDOT, CSRP\_DRG,  CSRP\_SRP | Table 3‑5 | C |  |
|  | Covariance matrix row 9 (In-track Thrust related)  (ALT\_COV\_TYPE = XYZ) | CTHR\_X, CTHR\_Y, CTHR\_Z,  CTHR\_XDOT, CTHR\_YDOT,  CTHR\_ZDOT, CTHR\_DRG,  CTHR\_SRP, CTHR\_THR | Table 3‑5 | C |  |
|  | Covariance Matrix (ALT\_COV\_TYPE = CSIG3EIGVEC3) | N/A | Table 3‑5 | C |  |
|  | Comment  (ALT\_COV\_TYPE = CSIG3EIGVEC3)) | COMMENT | Table 3‑5 | C |  |
|  | Covariance eigenvalues and eigenvectors  (ALT\_COV\_TYPE = CSIG3EIGVEC3) | CSIG3EIGVEC3 (12 double values separated by spaces) | Table 3‑5 | C |  |
|  | Additional covariance meta-data | N/A | Table 3‑5 | O |  |
|  | Comment | COMMENT | Table 3‑5 | O |  |
|  | Atmospheric density forecast error | DENSITY\_FORECAST\_UNCERTAINTY | Table 3‑5 | O |  |
|  | Minimum covariance scale factor | CSCALE\_FACTOR\_MIN | Table 3‑5 | O |  |
|  | Covariance scale factor | CSCALE\_FACTOR | Table 3‑5 | O |  |
|  | Maximum covariance scale factor | CSCALE\_FACTOR\_MAX | Table 3‑5 | O |  |
|  | Screening data source | SCREENING\_DATA\_SOURCE | Table 3‑5 | O |  |
|  | Drag position consider parameter | DCP\_SENSITIVITY\_VECTOR\_POSITION | Table 3‑5 | O |  |
|  | Drag velocity consider parameter | DCP\_SENSITIVITY\_VECTOR\_VELOCITY | Table 3‑5 | O |  |
|  | CDM User-Defined Parameters | N/A | Table 3‑6 | O |  |
|  | Comment | COMMENT | Table 3‑6 | O |  |
|  | User-defined parameter | USER\_DEFINED\_x | Table 3‑6 | O |  |

1. VALUES FOR SELECTED KEYWORDS  
     
   (NORMATIVE)

The values in this annex represent the recommended values for selected keywords present in the CDM message. For details and descriptions of the keyword interpretations, the reader is directed to ANNEX F. The message creator should seek to confirm with the recipient(s) that their software can support the selected keyword value, particularly for more complex content such as reference frames, orbital elements, and covariance definitions.

These recommended values are stored on the SANA Registry, globally accessible on the CCSDS SANA registry website located at:

<https://sanaregistry.org/r/navigation_standard_registries/>

Note that the message creator or recipient may wish to automate processing of SANA registry normative content, which can be done by ingesting and processing of such content in electronic format. These formats can be accessed via the “Actions” link on each registry, e.g. for the Orbital Elements registry, a comma separated value (CSV) format can be exported at: <https://sanaregistry.org/r/orbital_elements?_export=csv> and a JavaScript Object Notation (JSON) format at: <https://sanaregistry.org/r/orbital_elements?_export=json>. Note that both the registry and these electronic data formats specify the number of vector elements corresponding to each keyword value.

Exchange partners may submit additional (new) keyword values for consideration of future inclusion into the SANA registry by submitting a detailed email request (mailto:info@sanaregistry.org) per annex C, section C2. The CCSDS Area or Working Group responsible for the maintenance of the CDM at the time of the request is the approval authority. Until a suggested value is included in the SANA registry, exchange partners may define and use values that are not listed in the SANA registry if mutually agreed between message exchange partners.

* 1. MESSAGE ORIGINATORS

The set of recommended values for the ORIGINATOR keyword is enumerated in the SANA Registry of Organizations, located at:

<https://sanaregistry.org/r/organizations>

* 1. SPACE OBJECT CATALOG NAMES

The set of recommended values for the CATALOG\_NAME keyword is enumerated in the SANA Registry of Space Object Catalogue Names, located at:

<https://sanaregistry.org/r/space_object_catalog>

* 1. REFERENCE FRAME CENTERS AND THIRD-BODY PERTURBATIONS

A set of allowed values for the reference frame center keywords (ORBIT\_CENTER, and N\_BODY\_PERTURBATIONS) is enumerated in the SANA Registry of Orbit Centers, located at: <https://sanaregistry.org/r/orbit_centers>. It should be noted that these values may also be useful to specify another platform (satellite, airframe, ground vehicle, etc.) as the reference frame origin to permit the specification of relative positional state time history data. In this case, message authors shall clearly communicate to recipients that the orbit center is not a gravitational center, that propagation of ephemeris vectors or extrapolation of ephemeris start/stop states is not advisable, and that interpolation of state time histories should not be accomplished using classical orbit propagation forces (e.g., gravitational constants, drag).

* 1. Celestial body reference frames

A set of allowed celestial body reference frame values for the **OEB\_PARENT\_FRAME** keyword is enumerated in the *SANA Registry of Celestial Body Reference Frames*, located at:

<https://sanaregistry.org/r/celestial_body_reference_frames>

* 1. Orbit-relative reference frames

In addition to the above reference frames, maneuver and covariance data may be selected from the list of allowed orbit-relative reference frames using the **OEB\_PARENT\_FRAME** keyword values enumerated in the *SANA Registry of Orbit-Relative Reference Frames*, located at:

https://sanaregistry.org/r/orbit\_relative\_reference\_frames

**Note that two types of orbit-relative local reference frames exist: inertial and rotating. When transforming velocity terms between inertial and rotating frames, remember to properly incorporate the contribution.**

* 1. ATMOSPHERE MODELS

A set of allowed values for the ATMOSPHERIC\_MODEL keyword is enumerated in the SANA Registry of Atmosphere Models, located at:

<https://sanaregistry.org/r/atmosphere_models>

* 1. GRAVITY MODELS

A set of allowed values for the GRAVITY\_MODEL keyword is enumerated in the SANA Registry of Gravity Models, located at:

<https://sanaregistry.org/r/gravity_models>

* 1. Collision Probability Method

A set of allowed values for the COLLISION\_PROBABILITY\_METHOD keyword is enumerated in the SANA Registry of Collision Probability Methods, located at:

<https://sanaregistry.org/r/cdm_cpm/>

* 1. OPERATIONAL STATUS

A set of allowed values for the **OPS\_STATUS** keyword is enumerated in the *SANA Registry of Operational Status of Space Object*, located at:

<https://sanaregistry.org/r/operational_status>

* 1. OBJECT TYPES

A set of allowed values for the **OBJECT\_TYPE** keyword is enumerated in the *SANA Registry of Operational Status of Space Object*, located at:

<https://sanaregistry.org/r/object_types>

1. SECURITY, SANA, and patent CONSIDERATIONS   
     
   (INFormative)
   1. SECURITY CONSIDERATIONS
      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.

* + 1. 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.

* + 1. 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.

* + 1. 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.

* + 1. 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.

* + 1. 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.

* + 1. 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.

* + 1. 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.

* + 1. 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.

* + 1. 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.

* + 1. 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.

* 1. SANA CONSIDERATIONS

The following CDM-related items are registered with the SANA Operator:

* The CDM XML schema;
* A transform from the CDM XML to the CDM KVN version;

The following normative CDM elements should be selected from the SANA registry (See annex B):

* Values for the keywords ORIGINATOR, CATALOG\_NAME, ORBIT\_CENTER, GRAVITY\_MODEL, ATMOSPHERIC\_MODEL, and N\_BODY\_PERTURBATIONS,
* A list of options for the COLLISION\_PROBABILITY\_METHOD keyword; and
* Definitions of celestial body and orbit-relative reference frames for use with the keyword REF\_FRAME.

The general policy for changes to the CDM is Expert Review by the Working Group or Area responsible for the CDM standard. The registration rule for new entries in the registry is the approval of new requests by the CCSDS Area or Working Group responsible for the maintenance of the CDM at the time of the request.

* 1. PATENT CONSIDERATIONS

The recommendations of this document have no patent issues.

1. ABBREVIATIONS AND ACRONYMS   
     
   (Informative)

ADM Attitude Data Message

ASCII American Standard Code for Information Interchange

ASW Astrodynamics Support Workstation

AU Astronomical Unit

CA Conjunction Assessment

CATS Critical Angle to the Sun

CCSDS Consultative Committee for Space Data Systems

CDF Cumulative Distribution Function

CDM Conjunction Data Message

CSV Comma Separated Value

DCP Drag Consider Parameter

DRG Atmospheric Drag

EME2000 Earth Mean Equator and Equinox of J2000 (Epoch J2000)

GCRF Geocentric Celestial Reference Frame

GEO Geosynchronous Orbit

HBR Hard-Body Radius

ICD Interface Control Document

ICS Implementation Conformance Statement

ITRF International Terrestrial Reference Frame

JSON JavaScript Object Notation

KVN Keyword = Value Notation

LEO Low Earth Orbit

NDM Navigation Data Message

O/O Owner/Operator

OD Orbit Determination

OBS Observations

ODM Orbit Data Message

OEB Optimally Enclosing Box

RCS Radar Cross Section

RL Requirements List

RMS Root Mean Square

RSO Resident Space Object

RTN Radial, Transverse, and Normal

SANA Space Assigned Numbers Authority

SEDR Specific Energy Dissipation Rate

SEFI Space Environment Fragmentation Impact

SI International System of Units

SRP Solar Radiation Pressure

TCA Time of Closest Approach

THR Thrust

TVN Transverse, Velocity, and Normal

URL Uniform Resource Locator

UTC Coordinated Universal Time

VCM Vector Covariance Message

VMAG Visual Magnitude

XML Extensible Markup Language

XSLT Extensible Stylesheet Language Transformations

XYZ Cartesian coordinate system

1. RATIONALE AND REQUIREMENTS FOR  
     
   CONJUNCTION DATA MESSAGES   
     
   (Informative)
   1. 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:

1. 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.
2. Desirable Characteristics, which are not requirements, but are felt to be important or useful features of the Recommended Standard.
   1. PRIMARY REQUIREMENTS ACCEPTED BY THE CDM

Table E‑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 3‑2 |
| 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 [H2]). | Table 3‑4 |
| 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 [H2]). | Table 3‑3 |
| 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. | 6.3.2.9, 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 required in ISO 16158 (reference [H2]). | Table 3‑5 |
| 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 [H2]). | Table 3‑3 |
| 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 [H2]). | Table 3‑4,  Table 3‑5 |
| 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 3‑3,  Table 3‑5,  4.3.10, 6.3.3, 6.4.3 |
| 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 [H2]). | Table 3‑5 |
| 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 [H2]). | Table 3‑4 |
| 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 3‑4 |
| 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 [H2]). | Table 3‑3,  Table 3‑4, Table 3‑5 |
| 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 3‑3,  Table 3‑4, Table 3‑5 |
| 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 3‑4 |
| CDM-P17 | The CDM shall provide the threshold of close approach used by the originator in the screening. | This datum is required in order to assess the risk of collision and assess potential preventive measures. Cited as desirable by ISO 16158 (reference [H2]). | Table 3‑3 |
| CDM-P18 | The CDM shall provide the relative velocity of the two objects 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 desirable by ISO 16158 (reference [H2]). | Table 3‑3 |

Table E‑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 3‑2 |
| 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 [H2]). | Table 3‑3 |
| 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 3‑5 |
| CDM-D06 | 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 3‑3 |

1. TECHNICAL MATERIAL AND CONVENTIONS   
     
   (Informative)
   1. RELATIVE DATA

**SEFI\_COLLISION\_PROBABILITY:** The space environment fragmentation impact adjusted collision probability. The adjustment consists of reducing the collision probability by an order of magnitude if the collision is assessed as not having a major impact on the local space environment. This assessment is detailed in reference [H18] and is performed as follows:

1. Compute collision probability;
2. Determine the orbital regime;
3. If Low Earth Orbit (LEO), then determine (using the simple NASA Standard Breakup Model) if this collision is anticipated to generate more than 200 fragments of greater than 10 cm;
4. If this collision is assessed as an event which will \*not\* produce more than 200 fragments of greater then 10 cm, then downgrade the collision probability value by one order of magnitude (otherwise, use the collision probability value “as is”).

**MAHALANOBIS\_DISTANCE**: The miss distance normalized to the 1-sigma error dispersion of the combined error covariance in the direction of the relative position vector. It indicates how close the two objects are at the time of the predicted encounter, scaled to the uncertainty in positional knowledge along that direction.

Mahalanobis miss distance may be computed from , , and the dispersions (, which are the square root of the respective eigenvalues) and associated eigenvectors (of unit length) which define the eigenframe as follows:

Relative position vector is:

The relative position vector is:

From which:

**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 quasi-inertial coordinate system as defined and referred to by the RSW\_INERTIAL keyword value on the SANA registry’s orbit relative reference frames section (<https://sanaregistry.org/r/orbit_relative_reference_frames/>). 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 F‑1).

**SCREEN\_PC\_THRESHOLD**: The user-selected collision probability threshold used to identify whether a conjunction warrants notification and/or avoidance action.

**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 F‑1).

Comparison of 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 F‑1 : Definition of the RTN and TVN Coordinate Frames

**SCREEN\_TYPE**: Type of screening criteria (probability or shape), where shape can be either a sphere, ellipsoid or box of the screening volume used to screen the satellite catalog for possible conjunctors with Object1. If shape selected then the size will be specified by SCREEN\_VOLUME\_RADIUS or SCREEN\_VOLUME\_X/Y/Z as required.

* 1. 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).

**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.

**WEIGHTED\_RMS**:



Where

*yi* is the *i*th observation;

 is the estimate of *yi*;

*i* is the standard deviation of the *i*th measurement;

 is the weight associated with the *i*th measurement; 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.

**CSCALE\_FACTOR\_MIN and CSCALE\_FACTOR\_MAX:**

These covariance scale factors are designed to scale the POSITIONAL standard deviations (square root of the covariance diagonal matrix elements) to account for a priori knowledge that a covariance matrix does not fully represent the errors that an orbit estimation process and covariance propagation may have or incur. The scale factors are applied to the entire covariance matrix AFTER its propagation (i.e., one must not scale up the covariance matrix and then propagate it). The MIN and MAX values are intended to capture the anticipated range of scale factors that would be required to make the covariance reflect the anticipated errors at the time(s) of interest.

The scale factor is applied as follows:

* 1. OBJECT PHYSICAL PARAMETERS

**AREA\_PC**: The area (or cross-section) of the object used in the calculation of the probability of collision (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. AREA\_PC\_MIN and AREA\_PC\_MAX provide minimum and maximum bounding values for this area.

**HBR:** The object Hard-Body Radius (m), the radius of a sphere which encapsulates the physical object. This quantity is often used in the calculation of Probability of Collision.

**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 *CD•A/m*, where *CD* 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 *CR•A/m*, calculated using solar flux at 1 AU, where *CR* 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.

**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 accounts for 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



where,

 = drag acceleration vector (inertial)

 = velocity vector (inertial)

Average SEDR over the orbit determination interval is given by

*SEDR\_AVE =* 

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.

**Optimally Encompassing Box (OEB):** For a box-shaped satellite without appendages, the satellite’s volume in three-dimensional space and a corresponding OEB would have a one-to-one mapping.

For a satellite having solar arrays that extend from the spacecraft body structure, the OEB would extend from the main satellite body to encompass the deployed solar arrays as well.

The OEB shape is shown in figure F‑2 below. As illustrated, the OEB reference frame axes (depicted in red dotted lines) are defined by convention as follows:

* The OEB x-axis is along the **longest** dimension of the box (). This is sometimes referred to as the “span” of the space object.
* The OEB y-axis is along the **intermediate** orthonormal dimension ()
* The OEB z-axis is along the **shortest** orthonormal dimension ().

The box shape can easily represent a cube by setting all orthonormal dimensions equal. In the event that the longest two or three orthonormal dimensions are equivalent, is defined as the direction along one of those longest dimensions and the next as .

The OEB z-axis is always defined as: .



Figure F‑2: Depiction of Optimally-Enclosing Box and Definitions of MAX, INT, and MIN Orientation Vectors Relative to OEB Parent Fame

NOTE – Parent and body axis are shown in proximity to each other for display purposes only, but could generally be in any orientation as specified by a quaternion (defined in SANA at <https://sanaregistry.org/r/attitude_and_spacecraft_conventions>).

A fixed orientation of the Optimally Encompassing Box with respect to the user-specified “OEB\_PARENT\_FRAME” is defined using a **quaternion** that maps from the user-specified OEB\_PARENT\_FRAME to the Optimally Encompassing Box vector directions. The above figure shows the proper definitions and adopted sign conventions. The resulting transformation sequence is:

Where the frame transformation matrix [M] is a function of the quaternion components

The physical dimensions of the OEB (long, intermediate, and short dimensions) are specified via OEB\_MAX, OEB\_INT, and OEB\_MIN respectively.

The cross-sectional area as viewed along the OEB x, y, and z axes (long, intermediate, and short dimension directions) are specified via AREA\_ALONG\_OEB\_MAX, AREA\_ALONG\_OEB\_INT, and AREA\_ALONG\_OEB\_MIN, respectively. These projected areas can represent the actual cross-sectional area presented normal to each axis direction, which can be useful for drag, lift, and SRP force estimates. For example, the total cross-sectional area observed when viewed from an arbitrary unit vector direction [x y z] for estimation of drag forces could be:

TOTAL\_AREA = {AREA\_PC or AREA\_DRG or AREA\_SRP}+

NOTE – The last expression in the TOTAL\_AREA formula above is a dot product.

**Apparent-to-Absolute Visual Magnitude Relationship:** These parameters present the relationships to be used to map apparent to absolute visual magnitude for inclusion in a CDM. These equations, based on ANNEX H, Reference [H13], examine signal magnitude for reflected illumination by a Resident Space Object (RSO) that is exoatmospheric, meaning that its illumination by the Sun is not reduced or impeded by atmospheric transmission losses. The equations do not account for spatial distribution across multiple detectors, which involves characterizing the Point Spread Function of the system.

Definitions:

Effective area of the target [

Then point source irradiance reaching the sensor aperture [W/m2]

Distance from the sun to the target [m] (e.g. 1 AU = 1.4959787066×1011 m)

Distance from target to sensor []

Effective diameter of the target [

Exoatmospheric solar irradiance, nominally 1380 [] at 1 AU

Target Irradiance at Sensor without atmospheric loss [W/m2]

Ref. Visual Magnitude (Vega) Irradiance [2.77894 ]

General shadowing term accounting for the penumbra region’s influence [unitless, 0 < F ≤1, 0 = umbra, and 1 = full Sun illumination]

Solar Intensity ≈ 3.088374161×1025 [W/sr]

Intensity of reflected energy from target treated as a point source [W]

Geometric reflectance phase function [unitless, 0 < ≤1]

VMapparent Apparent visual magnitude

Critical Angle to the Sun (CATS) from sun to the sensor, as shown in figure F‑3 and measured at the observed target [rad]

Pi constant

Reflectance of the target [between 0 (none) and 1 (perfect reflectance)]

Effective transmission of the atmosphere [unitless, 0 < τ ≤ 1]

Given an optical sensor’s measured target entrance aperture radiance:

[W/m2]

, measured on the visual magnitude scale

or if known:

[W]

[W/m2]

[m2]

NOTES

1. *ATarget* is undefined in umbra (F=0=darkness), or no reflection ().
2. If reflectance is unknown, one can assume a standard reference reflectance of fifteen percent.

From which an effective diameter of the physical object can be roughly approximated as:

From the above equations, “normalized” to a 1 AU Sun-to-target distance, a phase angle of 0° and an example reference 40,000 km target-to-sensor distance (equivalent to a GEO satellite tracked at 15.6° elevation above the optical site’s local horizon), is obtained as:

= , from which:

=

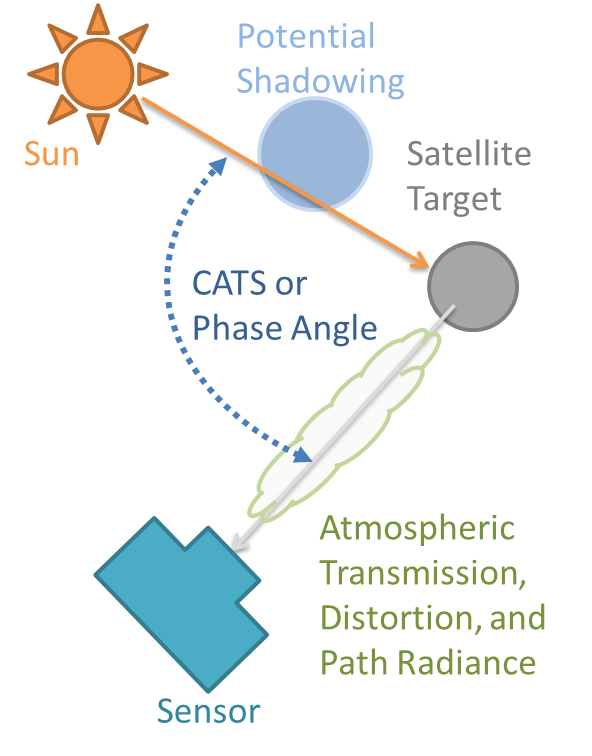


Figure F‑3: Depiction of Optical Viewing Critical Angle to the Sun (CATS) Phase Angle Geometry

* 1. Dynamic COnsider Parameters– Background and Application

**CDM Mean Position/Velocity State Vectors:** CDMs can specify the mean position/velocity state vectors of the primary and secondary satellites at TCA in a couple of reference frames. For Pc computation, these states must be converted (if necessary) into an inertial reference frame. This analysis denotes the resulting mean inertial position and velocity vectors at TCA for the primary and secondary objects as () and (), respectively.

**CDM Position/Velocity State Covariance Matrices:** CDMs specify position/velocity state covariances for the primary and secondary satellites using the radial-transverse-normal (RTN) coordinate frame. A CDM file specifies this symmetric 6×6 covariance for each object using keyword values for its 21 non-redundant matrix elements as follows

(1)

The RTN-frame covariance can be transformed into an inertial frame covariance by applying the following equation [H22, H23, H24]:

(2)

with the 6×6 transformation matrix having the form

(3)

with representing a 3x3 matrix of zeros. The 3x3 orthonormal matrix rotates vectors from the pseudo-inertial (non-rotating, instantaneously frozen) RTN frame into the inertial frame

(4)

with column vectors given by the three RTN unit vectors, calculable from the object’s inertial mean position and velocity vectors as follows

and and (5)

The 6×6 inertial frame covariance given in eq. (2) can each be decomposed into three 3×3 sub-matrices

(6)

with representing the marginalized covariance of the position vector, the marginalized covariance of the velocity vector, and position-velocity cross correlations.

When processing a CDM, eqs. (1)-(6) can be used to calculate inertial frame position/velocity state covariance matrices at TCA for the primary and secondary objects involved in a conjunction, and , respectively, as well as the marginalized position covariance matrices, and . (Note: because RTN is an object-specific frame of reference, these calculations must employ different rotation matrices, and , respectively.)

**Uncorrelated and Correlated Relative Position Covariance Matrices:** Collision probability estimation using the 2D-Pc method requires the conjunction’s inertial relative position miss-vector, , along with the associated miss-vector covariance matrix, [H19, H20, H4, H21]. If the primary and secondary position vectors are statistically independent (i.e., uncorrelated), then the relative position miss-vector covariance is given by their sum [H20]:

(7)

This approach provides a viable approximation for 2D-Pc estimation for conjunctions in which and have sufficiently weak correlation. However, recent analysis has demonstrated that some conjunctions have stronger covariance correlations, due to shared atmospheric density forecast components arising from the Astrodynamics Support Workstation (ASW) global density portion of the Dynamic Consider Parameter [H19]. In these cases, the miss-vector covariance can be corrected by removing the cross-correlated components as follows

(8)

with and denoting the atmospheric density 1-sigma relative uncertainties for the primary and secondary, respectively. The vectors and represent the sensitivity of the miss-vector covariance on global density relative uncertainties. (Note: see eq. (11) of reference [H19] and the related discussion for a derivation of eq. (8) given above, and a more detailed explanation of its components. Also, instead of using the symbol “” for 3×3 position covariances, reference [H19] uses the symbol “” which has already been used for another purpose in this analysis.)

CDM files provide the sigma values and sensitivity vectors required to calculate corrected relative position covariance matrices using eq. (8). These data are provided by the DENSITY\_FORECAST\_UNCERTAINTY, DCP\_SENSITIVITY\_VECTOR\_POSITION, and DCP\_SENSITIVITY\_VECTOR\_VELOCITY keywords

The first occurrence of the DCPsappear in the primary object section of the CDM, and provides (the DCP density forecast 1-sigma uncertainty), (the 3x1 DCP position sensitivity vector, expressed in the primary’s RTN frame), and (the 3x1 DCP velocity RTN-frame sensitivity vector). The second occurrence provides the corresponding DCPs for the secondary, i.e., , and The RTN frame sensitivity vectors provided in the CDM can be converted to inertial frame vectors using the transformation matrix defined in eq. (4) separately for each object

and and and (9)

**Uncorrelated and Correlated Relative Position/Velocity Covariance Matrices:** For statistically independent primary and secondary states, the relative position/velocity miss-state covariance is given by the sum of the covariances for the two objects [H20]:

(10)

This approach provides a viable approximation for conjunctions in which the primary and secondary position/velocity states have sufficiently weak correlation. In other cases, the miss-vector covariance can be corrected by removing the cross-correlated components as follows

(11)

with and again denoting the atmospheric density 1-sigma relative uncertainties for the primary and secondary objects, respectively. The 6x1 vector represents the sensitivity of the primary object’s miss-state covariance on global density relative uncertainties. The secondary object’s 6x1 sensitivity vector is defined similarly. (Again, see reference [H19] for more detail on these dynamic consider parameter uncertainties and sensitivity vectors.) The RTN frame sensitivity vectors provided in the CDM can be converted to inertial frame vectors using the transformation matrix defined in eq. (3) for each object

and (12)

**Pc Estimates with and without Covariance Correlation Correction:** Conjunction 2D-Pc values calculated using the miss-vector covariance in eq. (8) represent collision probabilities corrected for global atmospheric cross-correlation effects. These can differ from the uncorrected 2D-Pc values calculated using the covariance in eq. (7). Analysis of archived conjunctions indicates that this correction usually does not change Pc values appreciably, except in a minority of conjunctions that have both elevated drag energy dissipation rates and an appropriate combination of orbital geometries [H19]. Among this minority, however, the corrections can potentially elevate Pc values by a factor of two or more, meaning that accurate and conservative risk assessments for these cases rely on applying the covariance cross-correlation corrections made possible by the ASW system’s recent CDM modifications.

For low-velocity or multi-conjunction interactions, the statistically expected number of collisions (i.e., the “3D-Nc” value) can be calculated using the miss-state covariance matrix given in eq. (11), which then can be used to estimate the Pc value for the interaction, as explained in detail in reference [H25].

1. EXAMPLES   
     
   (INFORMATIVE)

Subsections G1.2 through G1.4 show examples of a CDM message in KVN. Subsection G1.2 includes only mandatory keywords and subsections G1.3 through G1.4 include optional keywords as well as mandatory.

NOTE – Example G1.2 is compatible with CDM V1 specification.

* + 1. An Example of a CDM in KVN with Only MANDATORY Keywords

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| CCSDS\_CDM\_VERS | = 2.0 |  |
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| ORIGINATOR | = CSpOC |  |
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| CTDOT\_R | = −1.006E−02 | [m\*\*2/s] |
| CTDOT\_T | = 4.041E−03 | [m\*\*2/s] |
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| CNDOT\_TDOT | = -1.091E-06 | [m\*\*2/s\*\*2] |
| CNDOT\_NDOT | = 5.529E-05 | [m\*\*2/s\*\*2] |
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| CTDOT\_R | = -1.016E-02 | [m\*\*2/s] |
| CTDOT\_T | = -1.506E-04 | [m\*\*2/s] |
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| CNDOT\_TDOT | = -4.594E-06 | [m\*\*2/s\*\*2] |
| CNDOT\_NDOT | = 5.178E-05 | [m\*\*2/s\*\*2] |



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| --- | --- | --- |
| CCSDS\_CDM\_VERS | = 2.0 |  |
| CLASSIFICATION | = UNCLASSIFIED |  |
|  |  |  |
| ORIGINATOR | = CSpOC |  |
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| CONJUNCTION\_ID | = 20100313T10HZ\_SAT\_A\_FEN\_1C\_DEB |  |
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| MAHALANOBIS\_DISTANCE | = 2.3 |  |
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| APPROACH\_ANGLE | = 35.2 | [deg] |
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| SCREEN\_TYPE | = SHAPE |  |
| SCREEN\_VOLUME\_SHAPE | = ELLIPSOID |  |
| SCREEN\_VOLUME\_FRAME | = RTN |  |
| SCREEN\_VOLUME\_X | = 200 | [m] |
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| OPERATOR\_EMAIL | = JOHN.DOE@SOMEWHERE.NET |  |
| EPHEMERIS\_NAME | = ODM |  |
| ODM\_MSG\_LINK | = EPHEMERIS\_SATELLITE\_A.oem |  |
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| ATMOSPHERIC\_MODEL | = MSISE-90 |  |
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| TRACKS\_USED | = 119 |  |
| RESIDUALS\_ACCEPTED | = 97.8 | [%] |
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| COMMENT Object1 Physical Parameters |  |  |
| AREA\_PC | = 5.2 | [m\*\*2] |
| AREA\_PC\_MIN | = 1.2 | [m\*\*2] |
| AREA\_PC\_MAX | = 5.04 | [m\*\*2] |
|  |  |  |
| CD\_AREA\_OVER\_MASS | = 0.045663 | [m\*\*2/kg] |
| CR\_AREA\_OVER\_MASS | = 0.000000 | [m\*\*2/kg] |
|  |  |  |
|  |  |  |
| APOAPSIS\_ALTITUDE | = 779 | [km] |
| PERIAPSIS\_ALTITUDE | = 765 | [km] |
| INCLINATION | = 86.4 | [deg] |
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| CRDOT\_T | = -5.476E-2 | [m\*\*2/s] |
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| CTDOT\_R | = -1.006E-02 | [m\*\*2/s] |
| CTDOT\_T | = 4.041E-03 | [m\*\*2/s] |
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| CNDOT\_TDOT | = -1.091E-06 | [m\*\*2/s\*\*2] |
| CNDOT\_NDOT | = 5.529E-05 | [m\*\*2/s\*\*2] |
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| ATMOSPHERIC\_MODEL | = MSISE-90 |  |
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| INTRACK\_THRUST | = NO |  |
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| OBS\_AVAILABLE | = 592 |  |
| OBS\_USED | = 579 |  |
| TRACKS\_AVAILABLE | = 15 |  |
| TRACKS\_USED | = 15 |  |
| RESIDUALS\_ACCEPTED | = 97.8 | [%] |
|  |  |  |
| INCLINATION | = 98.9 | [deg] |
| COMMENT Object2 Physical Parameters |  |  |
| AREA\_PC | = 0.9 | [m\*\*2] |
| RCS | = 2.27 | [m\*\*2] |
| CD\_AREA\_OVER\_MASS | = 0.118668 | [m\*\*2/kg] |
| CR\_AREA\_OVER\_MASS | = 0.075204 | [m\*\*2/kg] |
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| APOAPSIS\_ALTITUDE | = 786 | [km] |
| PERIAPSIS\_ALTITUDE | = 414 | [km] |
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| CTDOT\_R | = -1.016E-02 | [m\*\*2/s] |
| CTDOT\_T | = -1.506E-04 | [m\*\*2/s] |
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| CNDOT\_TDOT | = -4.594E-06 | [m\*\*2/s\*\*2] |
| CNDOT\_NDOT | = 5.178E-05 | [m\*\*2/s\*\*2] |
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| CCSDS\_CDM\_VERS | = 2.0 |  |
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| SCREEN\_TYPE | = SHAPE |  |
| SCREEN\_VOLUME\_SHAPE | = ELLIPSOID |  |
| SCREEN\_VOLUME\_FRAME | = RTN |  |
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| SCREEN\_VOLUME\_Y | = 1000 | [m] |
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| COLLISION\_PERCENTILE | = 20.0 50.0 80.0 |  |
| COLLISION\_PROBABILITY | = 3.2e-7 5.7e-7 2.8e-6 |  |
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| ALT\_COV\_TYPE | = XYZ |  |
| ALT\_COV\_REF\_FRAME | = EME2000 |  |
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| CRDOT\_T | = -5.476E-02 | [m\*\*2/s] |
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| CTDOT\_R | = -1.006E-02 | [m\*\*2/s] |
| CTDOT\_T | = 4.041E-03 | [m\*\*2/s] |
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| CNDOT\_TDOT | = -1.091E-06 | [m\*\*2/s\*\*2] |
| CNDOT\_NDOT | = 5.529E-05 | [m\*\*2/s\*\*2] |
| COMMENT Object1 Covariance in the XYZ Coordinate Frame | | |
| CX\_X | = 932.916411 | [m\*\*2] |
| CY\_X | = 942.228217 | [m\*\*2] |
| CY\_Y | = 1106.220534 | [m\*\*2] |
| CZ\_X | = -686.647753 | [m\*\*2] |
| CZ\_Y | = -788.748013 | [m\*\*2] |
| CZ\_Z | = 606.263054 | [m\*\*2] |
| CXDOT\_X | = -0.004239 | [m\*\*2/s] |
| CXDOT\_Y | = -0.017835 | [m\*\*2/s] |
| CXDOT\_Z | = 0.001456 | [m\*\*2/s] |
| CXDOT\_XDOT | = 0.000768 | [m\*\*2/s\*\*2] |
| CYDOT\_X | = -0.017445 | [m\*\*2/s] |
| CYDOT\_Y | = -0.007160 | [m\*\*2/s] |
| CYDOT\_Z | = 0.003966 | [m\*\*2/s] |
| CYDOT\_XDOT | = 0.000616 | [m\*\*2/s\*\*2] |
| CYDOT\_YDOT | = 0.000587 | [m\*\*2/s\*\*2] |
| CZDOT\_X | = -0.028730 | [m\*\*2/s] |
| CZDOT\_Y | = -0.029064 | [m\*\*2/s] |
| CZDOT\_Z | = 0.030090 | [m\*\*2/s] |
| CZDOT\_XDOT | = 0.001804 | [m\*\*2/s\*\*2] |
| CZDOT\_YDOT | = 0.001573 | [m\*\*2/s\*\*2] |
| CZDOT\_ZDOT | = 0.004455 | [m\*\*2/s\*\*2] |
| COMMENT Object2 Metadata |  |  |
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| ALT\_COV\_TYPE | = CSIG3EIGVEC3 |  |
| ALT\_COV\_REF\_FRAME | = EME2000 |  |
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| COMMENT Object1 Covariance in CSIG3EIGVEC3 format | | |
| CSIG3EIGVEC3 | = 140.697 25.552 14.989 -0.999982 0.005459  -0.002499 0.00598839 0.877100 -0.4802698  -0.00043000 -0.4802761 -0.8771172 |  |
| DENSITY\_FORECAST\_UNCERTAINTY | = 2.45030416E-01 |  |
| DCP\_SENSITIVITY\_VECTOR\_POSITION | -1.67441647E+01 3.68889831E+02 1.63797508E-01 | [m] |
| DCP\_SENSITIVITY\_VECTOR\_VELOCITY | -3.98670591E-01 1.09452965E-02 4.83454839E-04 | [m/s] |



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| <?xml version="1.0" encoding="UTF-8"?>  <cdm xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"  xsi:noNamespaceSchemaLocation="https://nav.sanaregistry.org/r/ndmxml\_unqualified/ndmxml-5.0.0-master-4.0.xsd"  id="CCSDS\_CDM\_VERS" version="2.0">  <header>  <COMMENT>Sample CDM - XML version</COMMENT>  <CREATION\_DATE>2010-03-12T22:31:12.000</CREATION\_DATE>  <ORIGINATOR> CSPOC </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\_TYPE>SHAPE</SCREEN\_TYPE>  <SCREEN\_VOLUME\_SHAPE>ELLIPSOID</SCREEN\_VOLUME\_SHAPE>  <SCREEN\_VOLUME\_FRAME>RTN</SCREEN\_VOLUME\_FRAME>  <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>  <segment>  <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>MSISE-90</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>579</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>  <physicalParameters>  <COMMENT>Object 1 Physical 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>  <APOAPSIS\_ALTITUDE units="km">796</APOAPSIS\_ALTITUDE>  <PERIAPSIS\_ALTITUDE units="km">765</PERIAPSIS\_ALTITUDE>  <INCLINATION units="deg">55</INCLINATION>  </physicalParameters>  <stateVector>  <COMMENT>Object1 State Vector</COMMENT>  <X units="km">2570.097065</X>  <Y units="km">2244.654904</Y>  <Z units="km">6281.497978</Z>  <X\_DOT units="km/s">4.418769571</X\_DOT>  <Y\_DOT units="km/s">4.833547743</Y\_DOT>  <Z\_DOT units="km/s">-3.526774282</Z\_DOT>  </stateVector>  <covarianceMatrix>  <COMMENT>Object1 Covariance in the RTN Coordinate Frame </COMMENT>  <CR\_R units="m\*\*2">4.142E+01</CR\_R>  <CT\_R units="m\*\*2">-8.579E+00</CT\_R>  <CT\_T units="m\*\*2">2.533E+03</CT\_T>  <CN\_R units="m\*\*2">-2.313E+01</CN\_R>  <CN\_T units="m\*\*2">1.336E+01</CN\_T>  <CN\_N units="m\*\*2">7.098E+01</CN\_N>  <CRDOT\_R units="m\*\*2/s">2.520E-03</CRDOT\_R>  <CRDOT\_T units="m\*\*2/s">-5.476E+00</CRDOT\_T>  <CRDOT\_N units="m\*\*2/s">8.626E-04</CRDOT\_N>  <CRDOT\_RDOT units="m\*\*2/s\*\*2">5.744E-03</CRDOT\_RDOT>  <CTDOT\_R units="m\*\*2/s">-1.006E-02</CTDOT\_R>  <CTDOT\_T units="m\*\*2/s">4.041E-03</CTDOT\_T>  <CTDOT\_N units="m\*\*2/s">-1.359E-03</CTDOT\_N>  <CTDOT\_RDOT units="m\*\*2/s\*\*2">-1.502E-05</CTDOT\_RDOT>  <CTDOT\_TDOT units="m\*\*2/s\*\*2">1.049E-05</CTDOT\_TDOT>  <CNDOT\_R units="m\*\*2/s">1.053E-03</CNDOT\_R>  <CNDOT\_T units="m\*\*2/s">-3.412E-03</CNDOT\_T>  <CNDOT\_N units="m\*\*2/s">1.213E-02</CNDOT\_N>  <CNDOT\_RDOT units="m\*\*2/s\*\*2">-3.004E-06</CNDOT\_RDOT>  <CNDOT\_TDOT units="m\*\*2/s\*\*2">-1.091E-06</CNDOT\_TDOT>  <CNDOT\_NDOT units="m\*\*2/s\*\*2">5.529E-05</CNDOT\_NDOT>  </covarianceMatrix>  </data>  </segment>  <segment>  <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> MSISE-90</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>592</OBS\_AVAILABLE>  <OBS\_USED>579</OBS\_USED>  <TRACKS\_AVAILABLE>15</TRACKS\_AVAILABLE>  <TRACKS\_USED>15</TRACKS\_USED>  <RESIDUALS\_ACCEPTED units="%">97.8</RESIDUALS\_ACCEPTED>  <WEIGHTED\_RMS>0.864</WEIGHTED\_RMS>  </odParameters>  <physicalParameters>  <COMMENT>Object2 Physical Parameters</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>  <APOAPSIS\_ALTITUDE units="km">768</APOAPSIS\_ALTITUDE>  <PERIAPSIS\_ALTITUDE units="km">414</PERIAPSIS\_ALTITUDE>  <INCLINATION units="deg">98.6</INCLINATION>  </physicalParameters>  <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 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1. INFORMATIVE REFERENCES   
     
   (INFORMATIVE)

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[H3] *Astrodynamics—Propagation Specifications, Technical Definitions, and Recommended Practices*. ANSI/AIAA S-131-2010. Reston, Virginia: AIAA, 2010.

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[H11] *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.

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1. ITEMS FOR AN INTERFACE CONTROL DOCUMENT (ICD)  
     
   (INFORMATIVE)
   1. STANDARD ICD ITEMS

In several places of this document, there are references to items that are recommended to be specified in an Interface Control Document (ICD) between participants that supplements an exchange of conjunction data. In general, an ICD is jointly produced by both participants in a cross-support involving the transfer of conjunction data. This annex compiles those recommendations into a single section. Although the Conjunction Data Messages described in this document may at times be used in situations in which participants have not negotiated ICDs, it is recommended that they be developed and negotiated whenever specified in this Recommended Standard.

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| **Item** | **Section** |
| 1. Detailed description of any user defined parameters | 3.6 |
| 1. Specification of whether KVN or XML formatted messages will be used. | 2.2 |
| 1. Methods of exchanging CDMs. | 3.1.3 |
| 1. Specific information security interoperability provisions that may apply between agencies. | C1.11 |

1. CHANGES VERSUS PREVIOUS VERSION   
     
   (INFORMATIVE)

This annex lists the differences between CDM 1.0 and CDM 2.0. The differences are divided into those which affect the content of conjunction data messages, and those which only affect the document.

* 1. Changes to Message

The following enhancements have been made to the Conjunction Data Message. Whilst the following changes have been made, backwards compatibility to CDM V1.0 has been ensured by the use of optional parameters:

1. Parameter clarifications
2. Improved message tagging (Classification, Conjunction ID, last and next message tagging)
3. Improved object definitions (Screening, Observations/OD, Covariance, Area PC)
4. Hard-Body Radius (HBR)
5. Optimally Enclosing Box (OEB)
6. Visual Magnitude (Vmag)
7. Radar Cross Section (RCS)
8. Mahalanobis Distance
9. Support for different covariance frames and types (RTN, XYZ, and Sigma/Eigenvector)
10. Covariance Realism
11. Cumulative Distribution Function of Probability of Collision (CDF of PC)
12. Dynamic Consider Parameters
13. Space Environment Fragmentation Impact (SEFI)
14. Specification of conjunction approach angle
15. Maneuver scheduling information
16. Facility for the specification of user defined parameters
    1. Changes in the Document
17. A new CCSDS repository for normative keyword values for navigation messages has been created at the SANA Registry, accessible on the Internet at: <https://nav.sanaregistry.org/r/navigation_standard_registries/>. (See annex B for details on the affected keywords and links to the content.)
18. Several annexes were added. Some are required by CCSDS rule changes, and some are for the provision of supplementary material.
19. CDM examples for KVN CDM and XML CDM that formerly appeared in sections 3.6 and 4.4 respectively, have been moved to an informative annex.