TraCSS

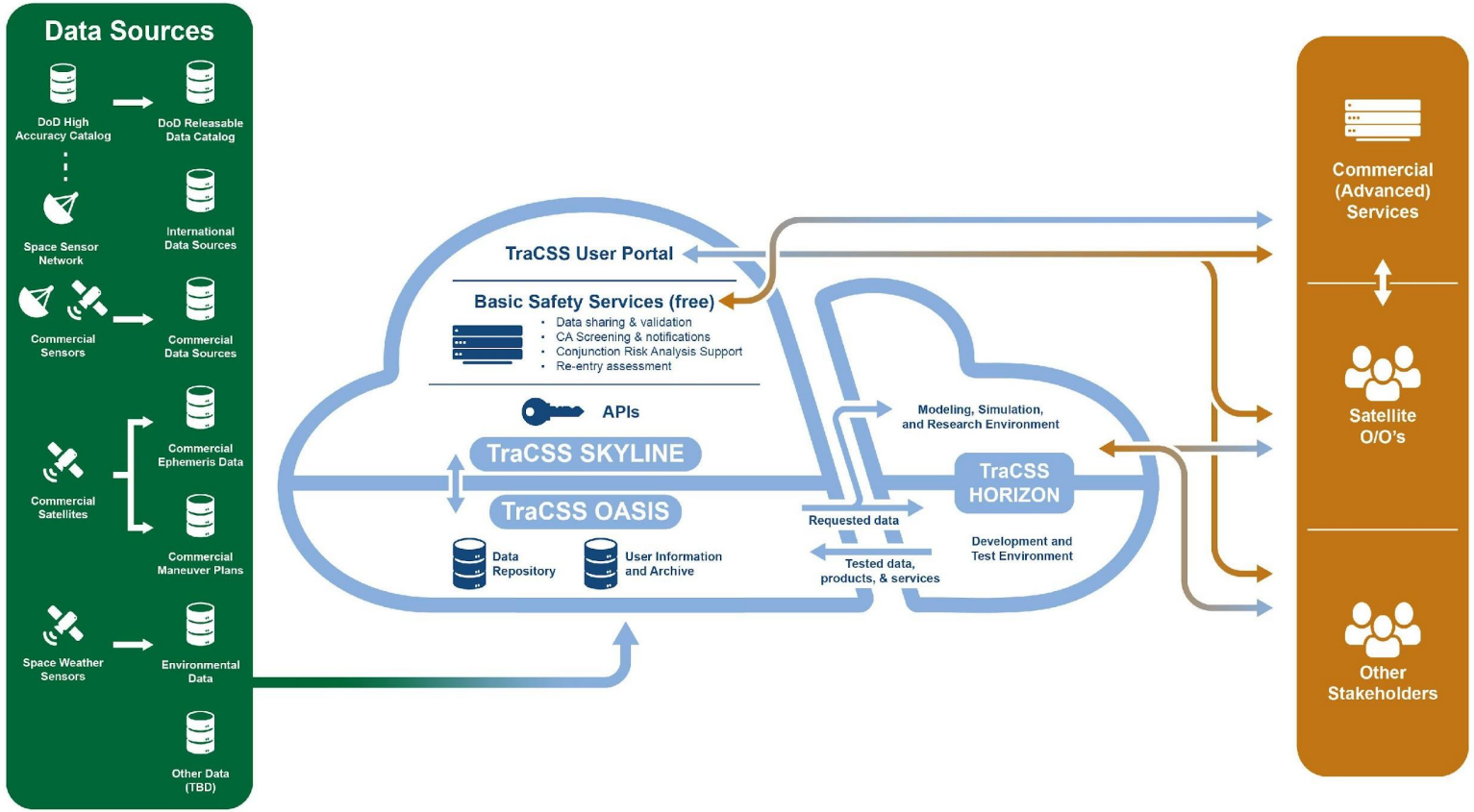
Join us on April 3 at 2:00 p.m. EDT
for the **TraCSS listening session** on

Space Data Standards & Formats: Conjunction Data Messages (CDMs)

Housekeeping for Listening Session

- The listening session is for 1 hour total time.
- Will be recorded and posted online to the TraCSS website afterwards
- Will be taking feedback but no Q&A in this session
- Agenda:
  - Welcome & Brief Overview of TraCSS - Christine Joseph, OSC
  - TraCSS Conjunction Data Messages (CDM) Proposal- Dr. Dianne Poster, OSC, NIST
  - Feedback Time
    - Registered Participants - 3 minutes each
  - Closing & Wrap-Up
  - Adjourn
- Next steps:
  - Written comments may be submitted per the guidelines in the posted document on the TraCSS webpage until 5:00 pm ET April 26, 2024
    - tracss.commerce@noaa.gov
  - Future listening sessions are planned for 2024 - will be announced on TraCSS webpage and via email blasts

Traffic Coordination System for Space - TraCSS



TraCSS & Conjunction Data Messages

Purpose:

- DOC has developed a proposal for conjunction data messages (CDM) fields in the CDM product that TraCSS will deliver for on-orbit conjunction assessment (CA).
- TraCSS proposes to use the format recommended by the Consultative Committee for Space Data Systems (CCSDS) CDM recommended standard 508.0.P1.0.1, understanding this version is under formal review by CCSDS.
- TraCSS plans to modify its approach as necessary to meet the needs of the SSA community.
- Section 3 of the proposal provides a comprehensive description of the proposed fields. This is not the final decision on what TraCSS will use.
- Today's listening session will focus on the proposed fields and receiving feedback.

TraCSS & Conjunction Data Messages

Background (slide 1 of 3):

- The CCSDS 508.0-B-15 specifies a standard message format for exchanging spacecraft conjunction information between providers of CA results and spacecraft owners and operators.
- The final product of CA results and is intended to provide spacecraft owner/operators with sufficient information to assess the risk of collision and design collision avoidance maneuvers, if necessary.
- The CDM can also tell the operator when insufficient information is available and so follow up tasking is required to reduce uncertainty.
- Therefore, the information exchanged within a CDM notifies the spacecraft operator(s) of possible conjunctions with another space object and enables consistent warning by different organizations employing diverse CA techniques.

TraCSS & Conjunction Data Messages

Background (slide 2 of 3):

- Conjunction information in CCSDS 508.0-B-15 includes data types such as:
  - identity of the affected objects
  - miss distance
  - probability of collision (Pc)
  - Time of closest approach (TCA)
  - closest approach relative position and velocity
  - Cartesian states of the affected objects at TCA, and
  - a covariance matrix that reflects the uncertainty of the states
- Full information describing the conjunction information contained in this message can be found in the document cited in footnote five of the proposal:
  - Conjunction Data Message. Issue 1. Recommendation for Space Data System Standards (Blue Book), CCSDS 508.0-B-1. Washington, D.C.: CCSDS, June 2013 (This current issue includes all updates through Technical Corrigendum 2, dated October 2021. Available at: https://public.ccsds.org/Pubs/508x0b1e2c2.pdf

TraCSS & Conjunction Data Messages

Background (slide 3 of 3):

- It is important to note the CCSDS CDM is currently undergoing revision because of the mandatory CCSDS five-year review, but the document 508.0-B-1 is in use today.
  - For example, the 18th and 19th (18 & 19) Space Defense Squadron (SDS), Combined Force Space Component Command, Vandenberg Space Force Base, California, USA, has leveraged the CCSDS CDM in operations.
  - It is their primary means of notifying an operator of a conjunction assessment.
  - A full description of the 18 & 19 SDS processes for on-orbit conjunction assessment and collision avoidance is provided in the document “Spaceflight Safety Handbook for Satellite Operators” Version 1.7, April 2023 (Appendix C)
  - Appendix C makes use of the CCSDS CDM 508.0-P-1.0.1, where the “P” stands for “pink book”.
  - This “P” version is the CCSDS draft recommended standard that is an update to 508.0-B-1 (where the “B” is a blue book”) and is released for formal review.
- The CCSDS CDM is also used at the NASA Johnson Space Center in support of human spaceflight operations and at Goddard Space Flight Center for the support of conjunction assessment risk analysis (CARA) operations.

TraCSS & Conjunction Data Messages

CDM Fields for TraCSS:

- The CDM will be the primary product that TraCSS will deliver for on-orbit CA.
- The format proposed CCSDS CDM 508.0-B-1, noting 508.0-P-1.0.1 will be used once that version's formal review is completed and the document is finalized by CCSDS.

In this presentation:

- **Table 1** is a comprehensive reference of the fields that are proposed be included in a TraCSS CDM for TraCSS Phase 1.0.
  - Note - CCSDS CDM data fields are comma-separated variable fields, in a particular order as shown, but a message string can be customized and vary in length.
- **Table 2** contains fields marked with an asterisk (*) in the proposal:
  - These will only have information in the CDM if the requisite input data is available to and distributable by TraCSS.
  - OSC is interested in feedback from the community on the operational impacts if such information is not included in a CDM.

TraCSS & Conjunction Data Messages

DOC welcomes feedback on the following topics:

1. whether information in the CDM fields is considered proprietary;
2. if there are operational considerations if the information in certain fields was not available;
3. if the proposed fields are representative of an operationally actionable data set assembled for a CDM;
4. if any of the proposed fields are considered to be not necessary; and
5. if there are additional fields that should be included in the proposed list.

Table 1. Proposed total list of fields for a TraCSS CDM (slide 1 of 6)

Keyword	Description	Example
CCSDS_CDM_VERS	CDM format version in the form of X.Y.	1.0
COMMENT	A comment can be placed here for reader's information. Currently 18 SPCS places the CDM ID in the comment section	CDM_ID:XXXXXXXXX
CREATION_DATE	File creation date/time in UTC	2015-07-04T12:00:00.000000
ORIGINATOR	Creating agency or operator	JSPOC
MESSAGE_FOR	Spacecraft name for which the CDM is provided	STARLINK-61
MESSAGE_ID	ID that uniquely identifies the CDM message.	000012345_conj_000054321_2022067143221_0651437225 6137
TCA	The Date and Time of the conjunction in UTC	2015-07-04T12:00:00.000000
MISS_DISTANCE	The overall separation distance of both objects at TCA in meters	437
RELATIVE_SPEED	The magnitude of the relative velocity vector in meters/sec. The speed at which both objects are moving relative to each other at TCA in meters/second	15031
RELATIVE_POSITION_R	The R component of Object 2's position relative to Object 1 in an RTN coordinate frame in meters	43.2, -574
RELATIVE_POSITION_T	The T component of Object 2's position relative to Object 1 in an RTN coordinate frame in meters	43.2, -57
RELATIVE_POSITION_N	The N component of Object 2's position relative to Object 1 in an RTN coordinate frame in meters	43.2, -574
RELATIVE_VELOCITY_R	The R component of Object 2's velocity relative to Object 1's velocity in an RTN coordinate frame in meters/second	-36.3, 41.7, 12971.8
RELATIVE_VELOCITY_T	The T component of Object 2's velocity relative to Object 1's velocity in an RTN coordinate frame in meters/second	-36.3, 41.7, 12971.8
RELATIVE_VELOCITY_N	The N component of Object 2's velocity relative to Object 1's velocity in an RTN coordinate frame in meter/second	-36.3, 41.7, 12971.8

Table 1. Proposed total list of fields for a TraCSS CDM (slide 2 of 6)

Keyword	Description	Example
COLLISION_PROBABILITY	If applicable, the probability of collision (Pc) calculated by 18 SPCS from values of 0.0 to 1.0	0.000003656957
COLLISION_PROBABILITY_METHOD	The method utilized to calculate probability of collision	FOSTER-1992
COMMENT Screening Option	The screening mode used by the 18 SPCS to predict the conjunction contained in the CDM. Options include stand-off radius, ellipsoid and covariance	Stand-Off, Ellipsoid, Covariance
COMMENT Screened with	The data used by 18 SPCS to generate the CDM	inertial state vector unknown state vector type
START_SCREEN_PERIOD	The start time in UTC of the screening period for the conjunction assessment	
STOP_SCREEN_PERIOD	The stop time in UTC of the screening period for the conjunction assessment	
SCREEN_VOLUME_SHAPE	Shape of the screening volume: ELLIPSOID or BOX.	
SCREEN_VOLUME_FRAME	Name of the Object1 centered reference frame in which the screening volume data are given. Available options are RTN and Transverse, Velocity, and Normal (TVN)	
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	
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	
SCREEN_VOLUME_Z	The N component size of the screening volume in the SCREEN_VOLUME_FRAME	
SCREEN_ENTRY_TIME	The time in UTC when Object2 enters the screening volume	
SCREEN_EXIT_TIME	The time in UTC when Object2 exits the screening volume	
COLLISION_PROBABILITY	If applicable, the probability of collision (Pc) calculated by 18 SPCS from values of 0.0 to 1.0	0.000003656957
COLLISION_PROBABILITY_METHOD	The method utilized to calculate probability of collision	FOSTER-1992

Table 1. Proposed total list of fields for a TraCSS CDM (slide 3 of 6)

Keyword	Description	Example
ORBIT_CENTER	The central body about which Object1 and Object2 orbit. If not specified, the center is assumed to be Earth.	EARTH, SUN
	FIELDS BELOW REPEATED FOR OBJECT 1 AND 2	
OBJECT	The object for which the metadata applies	OBJECT 1 OBJECT 2
OBJECT_DESIGNATOR	The SCC or NORAD CAT ID for the object	25544
CATALOG_NAME	The satellite catalog used for the object	DOD Catalog
OBJECT_NAME	The common name for the object	STARLINK-61, COSMOS 1408 DEB
INTERNATIONAL_DESIGNATOR	The International Designator for the object in a YYYY-DDDXXX format notating the year and day of launch followed by at least one capital letter to discern between objects of the same launch.	1998-06
OBJECT_TYPE	Category of type of object	PAYLOAD, ROCKET BODY, DEBRIS, UNKNOWN, OTHER
OPERATOR_CONTACT_POSITION	The contact position of the owner/operator of the object. Space-Track will place a URL for a query that will lead to this information	
OPERATOR_ORGANIZATION	The organization of the owner/operator of the object	SpaceX, Iridium, CNES
OPERATOR_PHONE	The phone number of the owner/operator of the object. Space-Track will place a URL for a query that will lead to this information	
OPERATOR_EMAIL	The e-mail of the owner/operator of the object. Space-Track will place a URL for a query that will lead to this information	
EPHEMERIS_NAME	The name of the ephemeris utilized if the data source is ephemeris	NONE MEME_25544_ISS_1651200_oper__unclassified.txt
ORBIT_CENTER	The central body about which Object1 and Object2 orbit. If not specified, the center is assumed to be Earth.	EARTH, SUN

Table 1. Proposed total list of fields for a TraCSS CDM (slide 4 of 6)

Keyword	Description	Example
COVARIANCE_METHOD	The method of which covariance is calculated. When covariance cannot be calculated, default values may be used. Caution should be used when using default values when calculating Pc	CALCULATED DEFAULT
MANEUVERABLE	The maneuver capability of the object	[Will reflect o/o inputted statement of capability, upon registration of satellite in TraCSS.]
REF_FRAME	Name of the reference frame for the provided state vectors	[Default] EME2000 for position and velocity (RTN/UVW) with rotation term for covariance
COMMENT Covariance Scale Factor	The scale that covariance is multiplied by	1.000000
COMMENT Exclusion Volume Radius	The radius of a sphere in meters to create a spherical volume representative of the object and used in the Pc calculation	5.000000
COMMENT Apogee Altitude	The apogee of the object in km	460
COMMENT Perigee Altitude	The perigee of the object in km	437
COMMENT Inclination	The inclination of the object in deg	60.7
COMMENT Operator Hard Body Radius	If input by an owner/operator, the Hard Body Radius of the object in meters	0.00
AREA_PC	The area of the object used in the Pc calculation in m2	2.2642
MASS	The mass of the object	

Table 1. Proposed total list of fields for a TraCSS CDM (slide 5 of 6)

Keyword	Description	Example
X	Object position vector X component in km	1670.352554
Y	Object position vector Y component in km	-6834.579872
Z	Object position vector Z component in km	-1430.950837
X_DOT	Object velocity vector X component in km/s	2.780391335
Y_DOT	Object velocity vector Y component in km/s	2.808606433
COMMENT DCP Density Forecast Uncertainty	The dynamic considers parameter (DCP) 1-sigma uncertainty of the relative atmospheric density for the specified object (given as a simple ratio). This is the uncertainty of the average atmospheric density exerting drag on the object, relative to the nominal (measured) atmospheric density	2.143370310000000E-0
COMMENT DCP Sensitivity Vector RTN Pos	The DCP position sensitivity vector expressed in the object's radial-transverse-normal (RTN) reference frame in meters. This sensitivity vector relates changes in the object's TCA position vector to variations in relative atmospheric density and is in meters	-7.345809012167026E+02 3.865957136169006E+05 -1.456925086066596E+02
COMMENT DCP Sensitivity Vector RTN Vel	The DCP velocity sensitivity vector relates changes in the object's TCA inertial velocity vector to variations in relative atmospheric density and is in meters/sec	-2.195009966872100E+02 2.630946954519584E-01 3.265607422364180E-01

Table 1. Proposed total list of fields for a TraCSS CDM (slide 6 of 6)

Keyword	Description
CR_R	Object covariance matrix [1,1] in m2
CT_R	Object covariance matrix [2,1] in m2
CT_T	Object covariance matrix [2,2] in m2
CN_R	Object covariance matrix [3,1] in m2
CN_T	Object covariance matrix [3,2] in m2
CN_N	Object covariance matrix [3,3] in m2
CRDOT_R	Object covariance matrix [4,1] in m2/s
CRDOT_T	Object covariance matrix [4,2] in m2/s
CRDOT_N	Object covariance matrix [4,3] in m2/s
CRDOT_RDOT	Object covariance matrix [4,4] in m2/s2
CTDOT_R	Object covariance matrix [5,1] in m2/s
CTDOT_T	Object covariance matrix [5,2] in m2/s
CTDOT_N	Object covariance matrix [5,3] in m2/s
CTDOT_RDOT	Object covariance matrix [5,4] in m2/s2
CTDOT_TDOT	Object covariance matrix [5,5] in m2/s2
CNDOT_R	Object covariance matrix [6,1] in m2/s
CNDOT_T	Object covariance matrix [6,2] in m2/s
CNDOT_N	Object covariance matrix [6,3] in m2/s
CNDOT_RDOT	Object covariance matrix [6,4] in m2/s2
CNDOT_TDOT	Object covariance matrix [6,5] in m2/s2
CNDOT_NDOT	Object covariance matrix [6,6] in m2/s2

Table 2. Proposed total list of fields for a TraCSS CDM – these will only have only have information in the CDM if the requisite input data is available to and distributable by TraCSS (slide 1 of 2)

Keyword	Description	Example
FIELDS BELOW REPEATED FOR OBJECT 1 AND 2		
*GRAVITY_MODEL	The name of the gravity model used for propagation	EGM-96: 36D 360
*ATMOSPHERIC_MODEL	The name of the atmospheric model used for propagation	JBH09
*N_BODY_PERTURBATIONS	The gravitational perturbation models used in a comma separated format	MOON, SUN
*SOLAR_RAD_PRESSURE	Indicates whether solar radiation pressure was used during the Orbit Determination (OD) of the object	YES NO
*EARTH_TIDES	Indicates whether solid Earth and ocean tides were used in the OD of object	YES NO
*INTRACK_THRUST	Indicates whether in-track thrust modeling was used for the OD and propagation of the object	YES NO
*TIME_LASTOB_START	The time in UTC of the start of the timespan that contains observations used in the OD. This time will start at the latest accepted observation	2015-07-04T12:00:00.000000
*TIME_LASTOB_END	The time in UTC of the end of the timespan that contains observations used in the OD. This time will end at the most recent accepted observation	2015-07-04T12:00:00.000000
*RECOMMENDED_OD_SPAN	The recommended time span for the OD of the object in days	2.76
*ACTUAL_OD_SPAN	The actual time span used in the OD of the object in days	2.76
*OBS_AVAILALBE	Total amount of observations available for the OD of the object	57
*OBS_USED	Actual number of observations used in the OD of the object	57
*RESIDUALS_ACCEPTED	The percentage of residuals accepted in the OD of the object	99.3

Table 2. Proposed total list of fields for a TraCSS CDM – these will only have only have information in the CDM if the requisite input data is available to and distributable by TraCSS (slide 2 of 2)

Keyword	Description	Example
*CD_AREA_OVER_MASS	The object's CD•A/m used in the propagation of the vector and covariance to TCA in m2/kg	0.161615504658
*CR_AREA_OVER_MASS	The object's CR•A/m used in the propagation of the vector and covariance to TCA in m2/kg	0
*THRUST_ACCELERATION	The object's acceleration in the In-track or R direction (RTN) used for propagating the state vector and covariance until TCA in m/s2	0 0.634
*SEDR	The average amount of energy being removed from an object's orbit due to atmospheric drag in W/kg	0.020492
*AREA_DRG	The effective area of the object exposed to atmospheric drag in m2	
*AREA_SRP	The effective area of the object exposed to solar radiation pressure in m2	

In addition, below is information included in the 19 SDS CDM COMMENT fields. These are not explicitly in the current finalized CCSDS standard. DOC welcomes comments on the use of this information in COMMENT fields vs. having a data field, for use by TraCSS:

1. CDM_ID
2. Screening Option
3. Screened with
4. Covariance Scale Factor
5. Exclusion Volume Radius
6. Apogee Altitude
7. Perigee Altitude
8. Inclination
9. Operator Hard Body Radius
10. DCP Density Forecast Uncertainty
11. DCP Sensitivity Vector RTN Pos
12. DCP Sensitivity Vector RTN Vel
13. TraCSS_ID: this would be the system ID at the database level. All data relationships should be built using a unique identifier other than NORAD_ID due to the volatility of a potential NORAD_ID. This can be used within the comment field.

TraCSS & Conjunction Data Messages

In summary, the TraCSS Phase 1.0 CDM fields recommendations are to:

1. include all CCSDS CDM 508.0-B-1 fields, even for those fields that are not published in the 19 SDS CDM;
2. continue to use COMMENT fields for instances where the 19 SDS CDM uses COMMENT fields, until CCSDS CDM 508.0-B-1 is updated;
3. add new keywords for data that the 19 SDS CDM currently has in COMMENT fields where there are no existing keywords to help with tagging, indexing, and searching;
4. announce TraCSS will deprecate TraCSS CDM COMMENT fields when CCSDS CDM 508.0-B-1 is updated; and
5. continuously work with the CCSDS Navigation Working Group on the CCSDS CDM standard.

TraCSS & Conjunction Data Messages

DOC welcomes feedback on the following topics (slide 1 of 2):

1. whether information in the CDM fields is considered proprietary;
2. if there are operational considerations if the information in certain fields was not available;
3. if the proposed fields are representative of an operationally actionable data set assembled for a CDM;
4. if any of the proposed fields are considered to be not necessary; and
5. if there are additional fields that should be included in the proposed list.

TraCSS & Conjunction Data Messages

DOC welcomes feedback on the following topics (slide 2 of 2) – these items are of particular interest:

1. OSC proposes default reference frames of EME2000 for position and velocity and (RTN/UVW) with rotation term for covariance.
    1. Are there significant operational impacts to the community if such reference frames are the default?
    2. Are there alternate reference frames OSC should consider as the default, and why?
2. Fields marked with an asterisk (*) in Table 2 will only have information in the CDM if the requisite input data is available to and distributable by TraCSS.
    1. OSC is interested in feedback from the community on the operational impacts if such information is not included in a CDM.

Acknowledgements

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