| **Page** | **Section** | **Line** | **Type** | **Comment/ Rationale** | **Source of Comment (Name/Agency)** | **Suggested Disposition** | **Disposition**  **(Completed by Principal Editor)** |
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|  |  |  |  | Covariance confidence/realism – current hot topic in collision avoidance (explained later), which could be accomplished with one new keyword | ESA/SDO CA |  | 04 May 2019 – DO/BDS - See covariance confidence from Cheryl (below) |
|  |  |  |  | Information about next update – very useful for maneuver planning or go/no-go decisions | ESA/SDO CA |  | 09 May 2019 – Mtn. View - This would be useful as an option. Also agreed to reintroduce this to the ODM.  19 Jun 2019 – BDS –Addressed by “Next release of CA” below |
|  |  |  |  | Some clarification on AREA\_PC use (maybe make a requirement it is the area used for Pc?) and add a range of areas | ESA/SDO CA |  | 04 May 2019 – DO/BDS - Agree. This is \*not\* intended to be the area used for drag or SRP modeling, for example.  09 May 2019 – Mtn. View - Note the AREA\_MIN and AREA\_MAX implied by “range of areas” Alexandru will seek clarification  07 Jun 2019: AM - Right now, it seems JSpOC is filling in AREA\_PC with either RCS or some default values, and using something else when computing the collision probability. We should maybe add a clarification of the use of AREA\_PC, as the current definition is *the actual area of the object*. It should be something along the lines of the area (or cross-section) used to compute Pc.  19 Jun 2019 – BDS – Agree, clarification will be added.  15 Oct 2019 – BDS –US stakeholder telecon - 18SPCS will use new RSO parameters instead of AREA\_PC. |
|  |  |  |  | Have a “Next release of CA” | ESA/SDO CA |  | 09 May 2019 – Mtn. View - Alexandru will get clarification on whether this is the same as “Information about next update” above.  07 Jun 2019: AM - There are two items that would be useful here:  1) Have a previous message epoch, previous message id, and next message epoch (same as the RDM). The last one would allow operators to know when a new CDM will be issued an plan their CA maneuver decisions accordingly.  2) Have some way of specifying whether the next CDM is expected to be based on new observation data, or the same observation as the previous one. Right now, you have to wait for the next CDM and dig through to see if the *optional* TIME\_LASTOB\_START and TIME\_LASTOB\_END have changed. It might make sense to have some kind of OBSERVATIONS\_SCHEDULED\_BEFORE\_NEXT\_MESSAGE = YES/NO keyword with the other three mentioned above.  19 Jun 2019 – BDS – Agree, RDM message tags will be added along with observation tag. |
|  |  |  |  | Eliminate using message IDs in a comment field (as JSpOC is doing now, where they have one message ID in a comment, and one in the actual message using the ID keyword) | ESA/SDO CA |  | 04 May 2019 – DO/BDS - Fully agree – we need to add CONJUNCTION\_ID to the CDM std.  09 May 2019 – Mtn. View - Dan to confirm with 18SPCS that they are requesting a field to uniquely identify a specific conjunction event. Also ask if there are any other IDs they see the need for.  Also to get clarification on what their “CDM\_ID” is (seems like that should be the MESSAGE\_ID)  Also confirm with 18th that they will be modifying their ORIGINATOR to use CSPOC or 18SPCS instead of JSPOC.  15 Oct 2019 – BDS – US Stakeholder Telecon - will add CONJUNCTION\_ID to CDM. |
|  |  |  |  | Other small improvements (some caused by JSpOC use) | ESA/SDO CA |  | 09 May 2019 – Mtn. View - We’ll take the action to investigate covariance realism tests and how those might operationally be incorporated, but at the same time, we interpret the JAC plot to be a request for (at a minimum) SCALE\_FACTOR\_MIN and SCALE\_FACTOR\_MAX  15 Oct 2019 – BDS – US Stakeholder Telecon – Will add covariance realism and scale factor parameters. |
|  |  |  |  | The CDM message should be changed to include full precision (15 digits?) for the state error covariance matrices. | Newman/NASA |  | 09 May 2019 – Mtn. View - Use a “should” clause to drive better practice.  See below, incorporating new research into required digits of precision. Agree that “full precision” would be a conservative but potentially workable approach.  19 Jun 2019 – BDS – Add section suggesting required precision as per paper. |
|  |  |  |  | Allow for the modeling of constant-duration thrust in 3 dimensions (RTN).  Currently the CDM only supports the in-track modeling. | Newman/NASA |  | 09 May 2019 – Mtn. View - Agree. Also agree to strive for backwards compatibility, perhaps as deprecated optional content “for the purpose of backward compatibility”  15 Oct 2019 – BDS – US Stakeholder Telecon – Agree that this should be left for future version of CDM in order to reduce scope of modification of next draft and overhead of ensuring backwards compatability |
|  |  |  |  | We would like to see consistency of the covariance to the supplied state. Ideally this would be an equinoctial state (including retrograde flag) with an equinoctial covariance. However, at a minimum it would be beneficial to have ECI covariances to go along with ECI state. This rotation and covariance requires the least amount of calculations to compute Pc. | Newman/NASA |  | 04 May 2019 – DO/BDS - Agree that the orbit state and its covariance should be consistent, and I think they already are.  What I think you are saying, though, is that the orbit state and covariance should be using the exact same Cartesian or orbit element set definition. While we agree this would be workable, we don’t feel that this improves the accuracy of the Pc computation.  We also know that many missions do not have equinoctial elements defined, whereas they do have RTN for covariance and ECI for orbits already coded up.  Dan to take action to contact 18th to discuss the RTN limitation and a desire to generalize and make consistent with other current CCSDS standards. Also, still looking for elements 7, 8 and 9 for the covariance. Patrick to check into usage of 7,8.9 at JSC.  15 Oct 2019 – BDS – US Stakeholder Telecon – Agree to implement reference frame tags for state and covariance but equinoctial states will be reserved for a future CDM update due to complexity of implementing. RTN tags are going to be replaced by XYZ so paving the way for future alternative frame types. |
|  |  |  |  | By default the CDMs should come in ECI instead of TDR. | Newman/NASA |  | 04 May 2019 – DO/BDS - Disagree, because orbit states are most precisely known (and consistent) in an earth-relative frame (because errors or discrepancies in EOP are eliminated).  09 May 2019 – Mtn. View - In long-term, would advocate that other reference frames and element sets be supported (e.g., per SANA registries). But would prefer that this get addressed in the proposed “super message” construct rather than putting a lot of duplicative effort into the individual standards.  ITRF and GCRF need to generically be added to SANA  15 Oct 2019 – BDS – US Stakeholder Telecon, reference frame tags will be implemented in next draft. |
|  |  |  |  | Expanded significant digits. The CDM does not expand to the same significant digits as internal 18 SPCS Astrodynamics Support Workstation (ASW) .CNJ files. The lower significant digits have been shown to cause non-positive definite covariances. | Newman/NASA |  | 04 May 2019 – DO/BDS - Fully agree - The concern raised over positive definiteness is valid. Over a 3-yr period, 5% of covariances in CDMs from 18SPCS were found to not be positive definite.  So to address this, we plan to incorporate findings from new covariance digits-of-precision studies (Alfano), methods to “fix” a non-positive definite covariance (Alfano) and implications of NPD covariances (Hejduk).  19 Jun 2019 – BDS – Precision already addressed in previous comment. |
|  |  |  |  | Add Dynamic consider parameters. Two components for both objects, frontal area and density forecast. | Newman/NASA |  | 09 May 2019 – Mtn. View - Dan to seek more detail here from NASA and 18th – what do these parameters work, and are these too implementation-centric?  15 Oct 2019 – BDS – US Stakeholder Telecon – A new user defined parameter section will be added to the CDM in the next draft, it is proposed that dynamic consider parameters may be specified here. |
|  |  |  |  | Add Individual object HBR | Newman/NASA |  | 04 May 2019 – DO/BDS - Agree. |
|  |  |  |  | The CDM should provide a reference to a specific set of CCSDS data products which represent the data used in the analysis. In particular, if a screening is ephemeris-based, that ephemeris should be linked/included, rather than extracting a instantaneous value (position, velocity, covariance) at TCA using some unspecified process. Of late, we have run into repeated instances of ephemerides we send to JSpOC for screening are not matching the state shown in the CDM. Without the specific ephemeris (or source) being used, it is virtually impossible to determine the cause of the problem. | Woodburn/AGI |  | 04 May 2019 – DO/BDS - Agree.  There already is a KVN of EPHEMERIS\_NAME (per comment several lines below). Propose to add ORBIT\_LINK, etc. (consistent with ODM) to address this.  Also want to point out that the “Super Message” we are conceiving will readily permit this. |
|  |  |  |  | The orbital data products need not be limited to the OEM format—the OPM or OMM formats could be used, as well. And in cases where the source of the orbital data does not want to provide sufficient detail to replicate the orbit (e.g., SP with DCA), the analysis could be performed with an ephemeris generated from the appropriate model and that ephemeris provided with the CDM. | Woodburn/AGI |  | 04 May 2019 – DO/BDS - Agree – see comments immediately above. |
|  |  |  |  | We’re not seeing the utility of the EPHEMERIS\_NAME keyword as it stands. It seems like more options would be needed to make it useful. For example, how would one know if a TLE or SP-based orbit solution were used? | Woodburn/AGI |  | 04 May 2019 – DO/BDS - You wouldn’t. Do we need to add a bunch of metadata about the source of data and its provenance?  19 Jun 2019 – BDS – See comments immediately above |
|  |  |  |  | We have seen many cases where results do not match and the differences are often in the tens of kilometers. This could be caused by improper interpolation of ephemerides that contain maneuvers, but without the actual ephemeris, it is impossible to tell or independently verify the CDM results. | Woodburn/AGI |  | 04 May 2019 – DO/BDS - Agree – see comments immediately above. |
|  |  |  |  | The CDM should accommodate new 9-digit SSC identifiers. We should also ensure that all current uses of comment fields to convey information are accommodated as proper entries in the CDM; check with 18SPCS and NASA/CARA, including another field for hard body radius that will complement the AREA\_PC field. | USAF |  | 04 May 2019 – DO/BDS - This renumbering appears to be on temporary hold. It is unclear if the external portrayal will use 5 characters (with one being a letter) vs transitioning to 9 digits.  19 Jun 2019 – BDS – Monitor for future update |
|  |  |  |  | Covariance parameter names should consistent with ODM and use XYZ instead of RTN, i.e.  CX\_X etc. | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - For the OCM we implemented an entirely new message to avoid backwards compatibility concerns. But those concerns will be present in the revised CDM. That said, seems like we want (and need) to draw the type of covariance from the SANA registry.  19 Jun 2019 – BDS – Action taken by DO to speak with 18SPCS regarding more generic state and covariance reference frames and use of SANA. See next comment also.  15 Oct 2019 – BDS – Subject discussed with 18SPCS and they did not see a problem with renaming RTN parameters to XYZ, this will therefore be done in the next draft |
|  |  |  |  | Covariance should be specifiable in ECI (default) as well as RTN and  therefore should also have a COV\_REF\_FRAME parameter to complement the REF\_FRAME parameter for the orbit state | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - Agree, per above.  15 Oct 2019 – BDS – US Stakeholder Telecon – RTN parmeters will be renamed XYZ and reference frame specification tag will be added for the covariance. |
|  |  |  |  | More decimal places on relative positions/velocities, in fact whole file should use same precision/decimal places or scientific notation? | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - We probably don’t want to enforce a numerical format beyond what the standard already allows.  That said, the CDM really needs to address required digits of precision for the various data types, much like i did in the OCM.  19 Jun 2019 – BDS – Addressed as part of Newman/NASA comment above, add section suggesting required precision. |
|  |  |  |  | MESSAGE\_FOR parameter does not seem to be used properly, JSpOC complete is as "CA", is it needed? | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - For us to discuss.  15 Oct 2019 – BDS – Comment withdrawn as not very important. |
|  |  |  |  | Really dislike mixed m/km units in file | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - Is this for more than just velocity (no page listed)? If not, then agree that we should use km/s for velocity.  09 May 2019 – Mtn. View - If we don’t modify the covariance for other reasons, we should leave it as m/s^2 etc. But if we update covariance, then we should alter covariance to be combinations of km, s, etc.  15 Oct 2019 – BDS – Whilst desirable the message works as currently formed and units are SI therefore change stored for future update to reduce overhead on next draft.. |
|  |  |  |  | OBJECT parameter is a little weird, could just have a valueless parameter of OBJECT1 and OBJECT2 | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - Suggest that we transition to the object naming now captured in the OCM.  15 Oct 2019 – BDS – Modification does not significantly improve message so reserfed for future update to reduce magnitude of modifications in next draft. |
|  |  |  |  | Tracking data parameters should be reviewed, are they needed/used, TIME\_LASTOB\_START, TIME\_LASTOB\_END, RECOMMENDED\_OD\_SPAN, ACTUAL\_OD\_SPAN, OBS\_AVAILABLE, OBS\_USED, RESIDUALS\_ACCEPTED, WEIGHTED\_RMS etc. | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - We propose to leave them in (and perhaps make them optional if they aren’t already).  This will support backwards compatibility as well. There is a history behind these parameters as well  19 Jun 2019 – BDS – Tags are already optional therefore no action required.  15 Oct 2019 – BDS – propose to remove tags, if required by an organization they may be placed in user defined parameter section. |
|  |  |  |  | Need to review what is being put in comment fields, should these be parameters? | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - Will be ongoing exercise |
|  |  |  |  | MANEUVERABLE parameter, what does N/A mean, surely YES/NO is sufficient, unless N/A is supposed to indicate NOT KNOWN? | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - Recommend changing to “N/A” to “UNKNOWN”. But if so, what backward compatibility would we want/need?  15 Oct 2019 – BDS – US Stakeholder Telecon – Due to possible backwards compatibility modification will be reserved for future update |
|  |  |  |  | INTRACK\_THRUST should be three dimensional THRUST\_X/Y/Z, this is also true of THRUST\_ACCELRATION parameter, would this also need a reference frame parameter? | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - Yes, agree. But if so, what backward compatibility would we want/need?  15 Oct 2019 – BDS – Due to possible backwards compatibility issues modification will be reserved for future update |
|  |  |  |  | COLLISION\_PROBABILITY  and COLLISION\_PROBABILITY\_METHOD should not be blank | Swinburne/UKSA |  | 04 May 2019 – DO/BDS - For us to discuss.  I actually believe that these should be optional, given that often the inputs required to compute it are not known. Note: i believe that the collision probability method should be captured in the SANA registry. Sal can help us come up with good names for the various methods  21 Oct 2019 – BDS – Clarification will be added that if information is not available then not to include keywords that are not mandatory. Add probability methods to SANA registry. |
|  |  |  |  | As currently implemented, the CDM provides the lower triangular elements of the covariance matrix, in a radial, tangent, normal (RTN) coordinate frame. This can be problematic, because there is no guarantee that the covariance reconstructed from such a representation will be positive definite. Not infrequently, non-positive-definite (NPD) covariances do occur in operational usage of CDMs. Consideration of other representations seems warranted.  There are many alternatives for representing a covariance matrix that ensure positive definiteness, and some of these also increase numerical precision, in terms of, for example, condition number. Alternatives that retain the precision of the original covariance include singular-value/eigenvalue decompositions, and UDUT (or LDLT) factorizations. The UDUT is a particularly efficient and compact representation and hence has been recommended as a best practice for navigation filtering. Alternatives that increase the precision are “square-root” factorizations, such as the Cholesky factorization. Not to be forgotten, if only for its readability, is a representation that utilizes standard deviations for its diagonal, and correlation coefficients for its off-diagonal elements; this method also increases numerical precision relative to a covariance representation. Unlike Cholesky however, the latter method does not require the original covariance to be strictly positive definite, or enforce that the reconstructed covariance will be positive either. Some of these alternatives may offer better interpolation properties as well.   * It may be useful to look at the COVARIANCE portion of the OCM and the (not-yet-populated) SANA registry for alternative covariance representations. Regardless, consistency between the OCM/COV, CDM, and SANA should be considered during CDM updates. | Grammling/NASA |  | 04 May 2019 – DO/BDS - Agree that the ODM and CDM should be consistent with the each other.  09 May 2019 – Mtn. View - We plan to stick with LTM. But if the ODM gets UDU etc., then the CDM could incorporate that as well.  But I don’t think the LTM (or UTM) are responsible for making the covariance non-positive definite; I think this is primarily driven by digits of precision used in the message.  See above (Newman) for response on addressing non-positive definiteness.  15 Oct 2019 – BDS – US Stakeholder Telecon – Reference frame tags will be added along with changing RTN reference to XYZ, this will pave the way for a future mod to add UDU etc.  23 Oct 2019 – CCSDS Fall Meetings – DO asked for eigenvector/value covariance representation to be added. |
|  |  |  |  | Regardless of the representation chosen to avoid transmission of NPD covariances, additional consideration to the coordinatization is warranted. In addition to RTN, the current Blue Book supports delivery of covariances in a tangent, velocity, normal (TVN) frame. The TVN frame would be expected to be superior to RTN for any orbit that is not perfectly circular, since its primary basis vector is the unit velocity vector, which is the direction of fastest growth when predicting covariances. If some Space Situational Awareness providers or owner/operators do not currently support delivery in the TVN frame, this should not be a sustainable justification for continuing to employ the inferior RTN representation. | Grammling/NASA |  | 04 May 2019 – DO/BDS - Agree that the CDM should allow specification of the covariance frame, consistent with the OCM’s use of the SANA registry (and the many reference frames that it supports).  19 Jun 2019 – BDS – Addressed by previous comments, see Swinburne/UKSA regarding COV\_REF\_FRAME and SANA registry |
|  |  |  |  | The current CDM does not provide any mechanism to provide the cross-covariance, which will be non-zero for providers that simultaneously estimate both primary and secondary objects, for example if their operations run something like AGI’s ODTK.  The updated CDM should consider inclusion of cross-covariance. | Grammling/NASA |  | 04 May 2019 – DO/BDS - This is a very good point. Propose that we work with Cheryl and Tom Johnson and Jim Woodburn to see if we can develop a workable cross-correlation message construct.  15 Oct 2019 – BDS – We acknowledge work currently being performed by NASA on this but it is felt that this modification would produce too great a testing overhead for the currently proposed V2 draft, it will be held for a future update. |
|  |  |  |  | The updated CDM should also consider adding a means for optionally identifying the covariance confidence. This can be specified as a free-text field with some example values (e.g. Wald test) or point to ICD content. | Grammling/NASA |  | 04 May 2019 – DO/BDS - Propose that we await the definition of this in the ODM and then make the CDM consistent with that.  15 Oct 2019 – BDS – US Stakeholders Telecon - CDM confidence free text field will be added. |
|  |  |  |  | Suggest that we examine the ADM, RDM, ODM etc. to see if any of their newly introduced parameters should also (for both utility and consistency purposes) be incorporated into this revision of the CDM. | NAV WG |  | 09 May 2019 – Mtn. View - For us to discuss.  15 Oct 2019 – BDS – US Stakeholders Telecon – Agree, this activity will be undertaken. |
|  |  |  |  | Consider the CDF (and implications) of Pc as some are advocating | NASA/Oltrogge |  | 15 Oct 2019 – BDS – US Stakeholders Telecon – Agree, this will be added but if it proves difficult to implement or contentious then it will be removed. |
|  |  |  |  | Consider the concept of space environmental fragmentation impact metric being proposed by CNES/NASA/et al | NASA/Oltrogge |  | 15 Oct 2019 – BDS – US Stakeholders Telecon – Agree, this will be added but if it proves difficult to implement or contentious then it will be removed. |
|  |  |  |  | Need to accommodate EPHEMERIS\_NAME\_A and EPHEMERIS\_NAME\_B (or something like it) | Alexandru |  | 15 Oct 2019 – BDS – We already have an EPHEMRIS \_NAME parameter and are proposing to add CCSDS links to external data, is this still required?  23 Oct 2019 – Darmstadt – BDS – Comment addresses by links to CCSDS products. |
|  |  |  |  | CATALOG\_NAME, OBJECT\_NAME, INTL\_DESIGNATOR and OBJECT\_DESIGNATOR should be consistent based on other stds (RDM and OCM) and SANA | NAV WG |  | 19 Jun 2019 – BDS - Agree |
|  |  |  |  | Really need individual object size/dimensions | NASA/Oltrogge, drawn from CNES CA Workshop roundtable discussion | Suggest adding estimated individual object dimensions as optimally-enclosing box and Yaw/Pitch/Roll orientation as contained in draft OCM | 15 Oct 2019 – BDS – US Stakeholder Telecon - Agree |
|  |  |  |  | Missing an increasingly popular CA metric: Mahalanobis miss distance (normalized by sigmas) | NASA/Oltrogge, drawn from CNES CA Workshop roundtable discussion | Please add | 15 Oct 2019 – BDS – US Stakeholder Telecon - Agree |
|  |  |  |  | RSO RCS missing. Consider this could be addition of principle and orthogonal RCS components. | NASA/Oltrogge, drawn from CNES CA Workshop roundtable discussion | Please add | 15 Oct 2019 – BDS – US Stakeholder Telecon - Agree |
|  |  |  |  | Radar frequency used to evaluate RCS is missing. | NASA/Oltrogge, drawn from CNES CA Workshop roundtable discussion | Please add | 15 Oct 2019 – BDS – US Stakeholder Telecon - Agree |
|  |  |  |  | RSO intrinsic visual magnitude is missing. | NASA/Oltrogge, drawn from CNES CA Workshop roundtable discussion | Please add | 15 Oct 2019 – BDS – US Stakeholder Telecon - Agree |
|  |  |  |  | Consider adding apogee and perigee heights of both objects – this helps convey the conjunction situation. | NASA/Oltrogge, drawn from CNES CA Workshop roundtable discussion | Please add | 15 Oct 2019 – BDS – US Stakeholder Telecon – Agree  23 Oct 2019 – CCSDS Fall Meetings – BDS - Will use Apsis/Periapsis as CDM can be used for non-Earth orbiting objects too. |
|  |  |  |  | Consider whether “characteristic signature” generic parameter(s) would be warranted | NASA/Oltrogge, drawn from CNES CA Workshop roundtable discussion | Consider | 15 Oct 2019 – BDS – US Stakeholder Telecon - Agree |
|  |  |  |  | Implement a user defined parameter section of the CDM which can be used for organization specific/legacy parameters | AFSPC/18SPCS/Oltrogge/Swinburne(UKSA) |  | 15 Oct 2019 – BDS – US Stakeholder Telecon – Agree. |
|  |  |  |  | Review definition of RTN reference frame in Annex E. | Brian Swinburne/UKSA |  | 23 Oct 2019 – CCSDS Fall Meetings – It was highlighted that the definition of the RTN reference frame in Annex E is not clear that the frame is quasi-inertial and not rotating (CNES Comment), will review definition (definition is in SANA) |