Main criteria for changes incorporated into the draft

1. Maximize backwards compatibility with the latest CCSDS TDM document
2. Evolve the TDM structure to facilitate modularization and support for real-time tracking data, in addition to the current file-based approach.
3. Ensure consistency with other navigation message implementations (e.g. ODM, ADM)
4. When adding new keywords, capture generic functionality that could apply to different tracking techniques and/or sensor types.
5. Incorporate necessary changes
    a. amendments to meta data
    b. new meta data
    c. new measurement types
    d. handling of relay systems
    e. assigning new data attributes
    f. incorporate onboard data types

List of Changes

1) Link the TDM to other MESSAGE_ID references: Incorporated changes to ensure consistency with ODM, ADM implementation.

    Added keywords: PREVIOUS_MESSAGE_ID, NEXT_MESSAGE_ID, ODM_MSG_LINK, ADM_MSG_LINK, PRM_MSG_LINK, RDM_MSG_LINK

    Removed keyword: EPHEMERIS_NAME (functionality covered under new ODM_MSG_LINK keyword)

2) Incorporate classification and special data handling information

    Added Keyword: CLASSIFICATION

3) Incorporate “MODALITY” functionality. Identify if data is REAL, SIMULATED, TEST, EXERCISE.
    Added keyword: TDM_BASIS (consistent with ODM “TRAJ_BASIS” from OEM and incorporates functionality)

4) Incorporated “COLLECTION_ID” functionality. A tracking session identifier, useful when several objects are tracked simultaneously. Helps the processing entity in correlation of observables to objects. Also, added “TASKING_ID” functionality. A tasking request ID the dataset is responding to.

    Added keyword: TDM_BASIS_ID (consistent with ODM and inclusion of collection and tasking functionality). Formed by Request ID followed by Collection ID, to the extent either are applicable to the TRACK and relate to the TRACK_ID.

5) Updated PARTICIPANT_n: Increase the number of participants to accommodate relay and constellation systems

    Modified PARTICIPANT_n field

Added a new MODE=RELAY

Added text explaining RELAY mode

6) Incorporate “TIMING_UNCERTAINTY” functionality. Expected uncertainty (1-sigma) in time tag values.

   Added keyword: TIMETAG_UNCERTAINTY

7) Incorporate new DATA_QUALITY keyword entries and enable DATA_QUALITY in the Data Section

   Added possible values to DATA_QUALITY: VERIFIED, INVALID. VERIFIED=coarse checks, and repurposing VALIDATED=meet requirements (maintains backwards compatibility)

   Included changes in different sections of the document to enable the possibility of incorporating quality “indicators” for each observable (also when corrections apply – see #8). Allow flexibility (still kept in meta to provide backwards compatibility).

8) Allow for designation of corrections for each data type and incorporate new CORRECTION_TIME keyword.

   Included changes in different sections of the document to enable the possibility of incorporating correction “indicators” for each observable (see #7)

   Added keyword: CORRECTION_TIME

9) Incorporate system configuration information, such as EQUIPMENT_ID_PATHn or CONFIGURATION_Px (Px= Xth Participant’s signal path), MODEM_ID, TIME_FREQ_REF_SOURCE_ID, OSCILLATOR_ID (esp for onboard systems with external oscillator option), DSP_ID, Multiple Access System: Center frequency of each link, beamformer ID

   Added keywords: FRONT_END_ID, SYSTEM_PATH, SYSTEM_MODE, TFR_ID

10) Incorporate new angle units, radians and “Angle Units” similar to “Range Units” implementation

    Added keyword: ANGLE_UNITS

11) Incorporate “ANT_TRACK_TYPE” functionality. Identify antenna tracking mode, Program or Autotrack (aided or unaided feedback loop)

    Added data keyword: ANGLE_MODE to the data section to allow mode changes)

12) Incorporated new “SYSTEM_STATUS” functionality in the data section, to allow for multiple system status updates to be captured in TDM’s. Allows functionality to include:
    - APERTURE_FILTERS n: name photometric filters applied during track
    - APERTURE_FILTER_ZERO_PT n: telescope photometric zero point and uncertainty for the filter
    - RECEIVER LOCK indicators (carrier lock, PN synch, PN lock)
    - SNR for signal on each PATH between two PARTICIPANTS
    - Beamformer Telemetry (bias, noise, thermal)

    Added keyword: SYSTEM_STATUS

13) Incorporate “CCD_BINNING” information: integer for bins

    Added CCD binning as an example under the new SYSTEM_PATH keyword (see #9)

14) Incorporate “OBSERVATION COVARIANCE (mixed)”. Symmetric, positive definite matrix for estimation error of each observable and cross-correlations. Used for space surveillance sessions.

    Added data keyword: OBSERVATION_COVARIANCE

15) Incorporate functionality for SENSOR_POSITION_VELOCITY_VECTOR: position/velocity vector for sensor at time of datum (EME2000; km, km/s) (useful for orbiting sensors, too)

    Already incorporated under #1 (allowing for use of new XYZ_MSG_LINK keywords to specify ODM or ADM messages that apply to a specific sensor. Added text to alternatively reference applicable files, as with prior EPHEMERIS_NAME keyword

16) Incorporate functionality for ANGLE_2_TRAIN (deg): offset of antenna in ANGLE_2 (elevation) that can vary during a track; differs from a constant CORRECTION_ANGLE_2

    Did not add ANGLE_2_TRAIN observable.

    Added CORRECTION_* keyword to data section. (provides flexibility to update corrections dynamically if needed)

17) Incorporate ANGLE_RATE observables. Measured or derived from angles.

    Added keywords: ANGLE_1_RATE, ANGLE_2_RATE

18) Incorporate ASTROMETRIC_STAR_COUNT (number of correlated stars used for frames) and PHOTOMETRIC_STAR_COUNT (number of correlated stars in photometric solution)

    Added data keywords: ASTROMETRIC_STAR_COUNT, PHOTOMETRIC_STAR_COUNT

19) Incorporate VISUAL_MAGNITUDE_UNCERTAINTY (uncertainty from frame photometric solution that calculates visual magnitude)

    Added data keyword: MAG_UNCERTAINTY

20) Incorporate PHOTOMETRIC_SNR (signal to noise ratio of total photometric content of evaluated signal)

    Added data keyword: PHOTOMETRIC_SNR

21) Incorporate FRAME LIMITING BRIGHTNESS (dimmest object expected to be detected in interrogated location)

    Added data keyword: FRAME LIMITING BRIGHTNESS

22) Incorporate MINIMUM_DETECTABLE_RCS (minimum object RCS detectable by waveform and sequence)

    Added meta keywords: MINIMUM_RCS, RCS UNITS (to include dBsm)

TO-DO List

1) Incorporate more comprehensive examples
2) Adjust Appendix areas accordingly
3) Incorporate ranging parameters
    a. Tone set (major through minors)
    b. PN Integration intervals
    c. Mod Index
    d. Etc
4) Incorporate new onboard measurements
    a. General (for example):
        - Data Latch Delay: time bias associated with latching data
        - Local Oscillator ID
    b. Accelerometers
    c. Crosslink
    d. Received Communications Link
    e. X-Ray Pulsar Navigation
    f. Optical (image) Navigation observation
    g. Point Solution
    h. NavSol from GNSS Receiver filter