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| **TRACKING DATA MESSAGE PROTOTYPING TEST PLAN/REPORT** |

FOREWORD

[Foreword text specific to this document goes here. The text below is boilerplate.]

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# INTRODUCTION

## PURPOSE

The purpose of this document is to provide the Test Plan for the Tracking Data Message (TDM) Version 2 (reference [3]). Subsequent to the execution of the Test Plan, the results of the testing will be documented in a document update.

## SCOPE

The scope of this document is test plans and test results for the new metadata and new data types incorporated in the TDM Version 2. Those metadata and data types tested as part of the TDM Version 1 will not be re-tested in this Test Plan. The TDM is part of the technical program of the CCSDS Navigation Working Group. The TDM Version 2 updated draft completed the CCSDS Agency Review in **<< insert date >>**; this process is described in reference [1].

Note that in applicable places the prototyping includes results based on modifications to the TDM document provided via the Review Item Discrepancy (RID) process of the Agency Review (see reference [4]), available internally through the Navigation Working Group.

## APPLICABILITY

This document applies only to the sections of the TDM Version 1 that are changed or added in the TDM Version 2. For the test plan and test results from the TDM Version 1, please see the Reference [2] in 1.7.

## RATIONALE

## DOCUMENT STRUCTURE

The first sections of this document describe the Test Plan for the prototyping activity; the last sections of the document provide a Test Report of the realized plan. This plan has been prepared by the members of the CCSDS Navigation Working Group who are coordinating the prototyping for their respective agencies.

## DEFINITIONS

## REFERENCES

The following publications are referenced in this document. At the time of publication, the editions indicated were valid. All publications are subject to revision, and users of this document 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] Organization and Processes for the Consultative Committee for Space Data Systems. Yellow Book - CCSDS Normative Procedures. Issue 4. April 2014.

[2] Tracking Data Message Prototyping Test Plan/Report, https://cwe.ccsds.org/moims/docs/MOIMS-NAV/Draft%20Documents/Tracking%20Data%20Message%20(TDM)/TDM%20Archive/TDM-Prototyping-Plan+Report-final-changesaccepted.pdf

[3] Tracking Data Message, CCSDS 503.0-P-1.1, Pink Book, May 2018.

# BLUE BOOK PROMOTION CRITERIA

The CCSDS Procedures Manual [1] states that for a Recommendation to become a Blue Book, the standard must be tested in an operational manner. The following requirements for an implementation exercise were excerpted from reference [1]:

“At least two independent and interoperable prototypes or implementations must have been developed and demonstrated in an operationally relevant environment, either real or simulated, unless a waiver of the interoperability testing requirement has been approved:”

This document will outline the Navigation Working Group’s approach to meeting this requirement for the TDM.

# SUMMARY CONCLUSION

**NOTE: FOLLOWING IS THE CONCLUSION FROM THE TDM VERSION 1. WE HOPE TO MAKE A SIMILAR STATEMENT AT THE CONCLUSION OF TDM VERSION 2 TESTING.**

TDM Prototypes were developed at three CCSDS member agencies: DLR, ESA, and NASA. A suite of ten test cases covered the interagency exchange and processing of a wide range of typical tracking data types. The tracking data were collected during operational tracking passes for three different spacecraft managed by three different member agencies. Operational tracking assets situated on four continents managed by four different tracking networks were used in the data collection. Based on this operational diversity and the positive test results, the TDM prototyping effort successfully addresses the Blue Book promotion criteria. It is thus proposed to approve the Tracking Data Message as a CCSDS Recommended Standard.

# TRACKING DATA MESSAGE TEST PLAN

## TEST PLAN OVERVIEW

The test of the TDM will exercise the following data types:

* Metadata (DATA\_TYPES Keyword)
* Doppler Counts
* Phase Counts
* Optical Magnitude
* Radar Cross Section
* XML Tracking Data Message

The following table identifies the test number, spacecraft, agencies, directionality of the message flow, and tentative schedule.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test#** | **Spacecraft** | **Agencies, Direction** | **Data Types** | **Schedule** |
| 1 | TBD | NASA/DSN => JPL/Nav | DATA\_TYPES Metadata | TBD |
| 2 | TBD | NASA/GSFC => TBD [CJG: Options: internal (LS-7) or FDF to 595), AGI, or perhaps WSC) | Doppler Counts | TBD |
| 3 | TBD | ESA => TBD | Phase Counts | TBD |
| 4 | Titan IIIC transtage debris [TBC] | ESA => TBD  ESA internal | Optical Magnitude | TBD |
| 5 | Envisat [TBC] | ESA => NASA/JPL  ESA internal | Radar Cross Section | TBD |
| 6 | TBD | NASA/JPL => ESA/ESOC | XML TDM | TBD |

The tests described in the remainder of this section will be conducted in order to meet the CCSDS requirements. In Section 5, the results of the testing will be presented when available.

## TEST PLAN DETAILS

### TEST CASE #1: DATA\_TYPES METADATA KEYWORD

For this test, one or more TDMs produced by NASA/DSN will be post-processed to add the DATA\_TYPES keyword in the metadata section to indicate which data types will follow in the TDM Data Section. The resultant modified TDM will be sent to JPL Navigation, which will process the TDM using its Monte navigation software (Inp.tdm function). The Test Data Sheet will be supplied by JPL Navigation. As a further test, it may be possible to modify the Monte navigation software (Out.tdm function) to produce TDMs containing the DATA\_TYPES metadata keyword.

**Expected Results**

It is anticipated that the JPL Navigation software prototype will utilize the DATA\_TYPES keyword to manage branching within its TDM processor function (Inp.tdm), and that the TDMs will be properly read such that the data in the Data Section can be ingested into the orbit determination process. Assuming that these criteria are met, the test will be considered successful. Extra credit is obtained for modifying the TDM processor function Out.tdm to produce TDMs that contain the DATA\_TYPES keyword. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

### TEST CASE #2: DOPPLER COUNTS

For this test case, NASA/GSFC Flight Dynamics Facility will send TDMs to <insert recipient> that contain the metadata and data keywords relevant to Doppler represented as counts for the <Landsat-7 or Terra> spacecraft. The TDMs will correspond to a definitive orbit ephemeris in the <to be supplied (CCSDS preferred)> format from which the Doppler Counts were derived. [CJG: Optionally, the counts may be real tracking data from the selected mission. The data type will be two-way Doppler from the Space Network (SN), also known as the Tracking and Data Relay Satellite System (TDRSS), S-band <Single Access or Multiple Access> coherent service. In addition to CCSDS TDMs, NASA/GSFC will provide the recipient with the same Doppler Count tracking data in a legacy-based Universal Tracking Data Format (UTDF) Tracking Data Messages, if required.

<The recipient> will process the CCSDS TDMs with their system and provide a file with time delimited Doppler conversion to Hertz [CJG: The conversions could be to m/s (Range-Rate), if that is a preferred unit. ]. Similarly, the recipient can process the UTDF TDMs with their system and provide a file with time delimited Doppler conversion to Hertz. The Hertz file(s) will be compared to file of Doppler in Hertz developed at GSFC FDF. These output files with Doppler in Hertz will be compared. All test artifacts will be sent back to NASA/GSFC.

**Expected Results**

Both the CCSDS TDM and the UTDF TDM files should produce identical results of Doppler converted to Hertz with resolution to 0.1 milliHertz. Meeting this criteria renders the test successful. In the event of discrepancies, troubleshooting will be conducted by the test participants.

### TEST CASE #3: PHASE COUNTS

For this test case, in the particular case of phase counts, it would be possible to get data from existing sources (e.g. GPS RINEX files) and produce a TDM than can then be processed. This may or not be representative depending on the original use case that triggered the inclusion of this data type in the TDM. Also the processing capabilities of the recipient may condition the feasibility of the test. Alternatively we can do an exercise similar to test #6 in the V1 prototyping where two TDMs are generated independently from pre-existing data and then the resulting TDMs are compared. If this is acceptable I can draft the test case assuming that the second agency will implement the generation of the second TDM from the same input data.

### TEST CASE #4: OPTICAL MAGNITUDE

For this test case, ESA/ESOC will provide a number of KVN TDMs containing optical magnitude, right ascension, and declination for Titan IIIC transtage debris to Agency X. The TDMs will contain the TIME\_SYSTEM, START\_TIME, STOP\_TIME, PARTICIPANT\_1, PARITICPANT\_2, MODE, PATH, ANGLE\_TYPE, and REFERENCE\_FRAME keywords in the metadata sections, and the ANGLE\_1, ANGLE\_2, and MAG keywords in the data sections. Both ESA/ESOC and Agency X will process these TDMs with their TDM v2 prototypes. Both agencies will produce plots of MAG against time for each TDM segment. The Test Data Sheet will be provided by ESA/ESOC.

It is anticipated that both the ESA/ESOC and Agency X prototype will generate the same magnitude variation plots and that they will match the values in the TDM. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

### TEST CASE #5: RADAR CROSS SECTION

For this test case, ESA/ESOC will provide a number of synthetically generated KVN TDMs containing RCS, azimuth, elevation, and range for Envisat to NASA/JPL. The TDMs will contain the TIME\_SYSTEM, START\_TIME, STOP\_TIME, PARTICIPANT\_1, PARITICPANT\_2, MODE, PATH, TIMETAG\_REF, RANGE\_UNITS, and ANGLE\_TYPE keywords in the metadata sections, and the ANGLE\_1, ANGLE\_2, RANGE, and RCS keywords in the data sections. Both ESA/ESOC and NASA/JPL will process these TDMs with their TDM v2 prototypes. Both agencies will produce plots of RCS against time for each TDM segment. The Test Data Sheet will be provided by ESA/ESOC.

**Expected Results**

It is anticipated that both the ESA/ESOC and NASA/JPL prototype will generate the same radar cross-section variation plots and that they will match the values in the TDM. Assuming that these criteria are met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

### TEST CASE #6: XML TRACKING DATA MESSAGE

Premise #1: Prototype Test Cases #1 through #5 have already established that the Version 2 modifications to the TDM can be used to support the exchange and processing of tracking data. In order for this premise to be true, execution of Test Case #6 must occur after Test Cases #1 through #5 have already been successfully completed.

Premise #2: The prototype testing performed at ESA/ESOC and NASA/JPL using the same (or similar) technical content as was described in Test Cases #1 through #5, and described in this document, has established that the flight dynamics content of the Version 2 modifications to the TDM standard can be rendered in an XML format.

For this test case, an updated version of the TDM/XML schema will be prepared (the updates will involve adding the new Version 2 Metadata Section keywords and Data Section keywords). TDMs in XML format containing all of the new Version 2 keywords will be created by JPL and transmitted to ESA/ESOC. In principle, the tests could involve conversion of the KVN TDMs used in Test Case #1 through Test Case #5 (but this is not a requirement; large TDMs may be truncated for this test). ESA/ESOC will process the received TDMs using the updated TDM schema. The test XML format TDMs will be added to the library of NDM/XML test cases for future use.

**Expected Results**

It is anticipated that the XML formatted TDMs will be valid when processed with the updated XML schema. Assuming that this criterion is met, the test will be considered successful. In the event of discrepancies, troubleshooting will be conducted by the participants in the test.

# TRACKING DATA MESSAGE TEST REPORT

## TEST RESULTS OVERVIEW

Engineers at participating agencies will prepare test data sheets as noted in the Test Plan Details above, and send them to the Navigation Working Group via email.

The Test Report Details will be found in the following sections of this document. A summarization of the test process and the recommendation of the Navigation Working Group may be found in Section 3 of the report. The report will be posted to the Navigation Working Group Common Working Environment (CWE) on the CCSDS web page at <http://cwe.ccsds.org> . The report will be submitted to the CCSDS Engineering Steering Group (CESG) and CCSDS Management Council (CMC), along with results of the Agency Reviews. At that time, a formal request will be submitted to the CMC for progression of the TDM to CCSDS Blue Book status.

Annex A contains a format for the test data sheets that will be used to report the results of individual tests.

## TEST RESULTS DETAIL

### TEST CASE #1: DATA\_TYPES METADATA KEYWORD

### TEST CASE #2: DOPPLER COUNTS

### TEST CASE #3: PHASE COUNTS

### TEST CASE #4: OPTICAL MAGNITUDE

### TEST CASE #5: RADAR CROSS SECTION

### TEST CASE #6: XML TRACKING DATA MESSAGE

1. SAMPLE Tracking Data Message Prototype Test Data Sheet

|  |  |  |
| --- | --- | --- |
| 1 | Test Case Number: |  |
| 2 | Report Date: |  |
| 3 | Program Under Test: | Tracking Data Message V2 (TDM) Prototype |
| 4 | Agencies Participating in this Test Case: |  |
| 5 | Agency Responsible for Prototype: | TDM Generation:  TDM Processing: |
| 6 | Prototype Version #  (if applicable): | TDM Generation:  TDM Processing: |
| 7 | Test Engineer: | TDM Generation:  TDM Processing: |
| 8 | Spacecraft: |  |
| 9 | Tracking Data Types: |  |
| 10 | Tracking Data Date/Time Range: |  |
| 11 | Variances from Expected Results: |  |
| 12 | Results (Pass, Partial Pass, Fail): |  |
| 13 | Comments: |  |

1. Acronyms

|  |  |
| --- | --- |
| CCSDS | Consultative Committee for Space Data Systems |
| CESG | CCSDS Engineering Steering Group |
| CMC | CCSDS Management Council |
| CWE | Common Working Environment |
| DLR | Deutsches Zentrum für Luft und Raumfahrt |
| ESA | European Space Agency |
| GSFC | Goddard Space Flight Center |
| ISRO | Indian Space Research Organization |
| JPL | Jet Propulsion Laboratory |
| NASA | National Aeronautics and Space Administration |
| RID | Review Item Discrepancy |
| TDM | Tracking Data Message |
| XML | eXtensible Markup Language |