The Consultative Committee for Space Data Systems

TRACKING DATA MESSAGE PROTOTYPING TEST PLAN/REPORT

DRAFT CCSDS RECORD

CCSDS 503.0-Y-1.8~~CCSDS 503.0-Y-1.7~~

DRAFT YELLOW BOOK
November 2019~~October 2019~~

FOREWORD

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

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- – Swedish Space Corporation (SSC)/Sweden.
- – Swiss Space Office (SSO)/Switzerland.
- – United States Geological Survey (USGS)/USA.

DOCUMENT CONTROL

Document	Title and Issue	Date	Status
CCSDS 503.1-Y-1??	TRACKING DATA MESSAGE PROTOTYPING TEST PLAN/REPORT , Issue DRAFT 1	February 2018	Initial draft
CCSDS 503.0-Y-1.3	TRACKING DATA MESSAGE PROTOTYPING TEST PLAN/REPORT , Issue DRAFT 1.3	April 2018	Updated draft with material from Cheryl, Alexandru, David
CCSDS 503.0-Y-1.4	TRACKING DATA MESSAGE PROTOTYPING TEST PLAN/REPORT , Issue DRAFT 1.4	June 2018	Updated draft with material Fran
CCSDS 503.0-Y-1.5	TRACKING DATA MESSAGE PROTOTYPING TEST PLAN/REPORT , Issue DRAFT 1.5	November 2018	Updated draft with material Fran
CCSDS 503.0-Y-1.6	TRACKING DATA MESSAGE PROTOTYPING TEST PLAN/REPORT Issue DRAFT 1.6	May 2019	Update for Spring 2019 Meetings
CCSDS 503.0-Y-1.7	TRACKING DATA MESSAGE PROTOTYPING TEST PLAN/REPORT Issue DRAFT 1.7	October 2019	Update for Fall 2019 Meetings
CCSDS 503.0-Y-1.8	TRACKING DATA MESSAGE PROTOTYPING TEST PLAN/REPORT Issue DRAFT 1.8	November 2019	Updates from Fall 2019 Meetings

CONTENTS

1 INTRODUCTION

1.1 PURPOSE

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

1.2 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. Unchanged metadata and data types tested as part of the TDM Version 1 will not be re-tested in this Test Plan as they are already being used in flight operations. 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 24 July 2018; this process is described in reference [1].

Note that in applicable places the prototyping includes results based on modifications to the TDM document (reference [3]) provided via the Review Item Discrepancy (RID) process of the Agency Review. These updated but unpublished versions of the TDM document are available internally through the Navigation Working Group.

1.3 APPLICABILITY

This document applies only to the sections of the TDM 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.

1.4 RATIONALE

A test plan and test report are required by the CCSDS standardization process documented in reference [1].

1.5 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.

1.6   DEFINITIONS

None.

1.7   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   Version   1   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 , 05-October-2007.

[3]   Tracking   Data   Message,   CCSDS   503.0-P-1.1,   Pink   Book,   May   2018, https://public.ccsds.org/Lists/CCSDS%205030P11/503x0p11.pdf.

2 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, along with the results of applying said approach.

3   SUMMARY CONCLUSION

NOTE: FOLLOWING IS THE CONCLUSION FROM THE TDM VERSION 1 with likely edits.

WE HOPE TO MAKE SUCH A STATEMENT AT THE CONCLUSION OF TDM VERSION 2 TESTING.

TDM Prototypes were developed at <<n>> CCSDS member agencies: <<list>>. A suite of <<n>> test cases covered the interagency exchange and processing of the new tracking data types.   The tracking data were collected during operational tracking passes for <<n>> different spacecraft managed by <<n>> different member agencies. Operational tracking assets situated on <<n>> continents managed by <<n>> 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 updated Tracking Data Message as a CCSDS Recommended Standard.

4 TRACKING DATA MESSAGE TEST PLAN

4.1 TEST PLAN OVERVIEW

Changes in the TDM Version 2 included revisions as follows:
- Metadata: DATA_TYPES, TRACK_ID, CORRECTION_ABERRATION_YEARLY, CORRECTION_ABERRATION_DIURNAL kKeywords added.
- Doppler Counts: Data keyword and associated metadata added.
- Phase Counts: Data keywords and associated metadata added.
- Optical Magnitude: Data keywords and associated metadata added.
- Radar Cross Section: Data keywords and associated metadata added.
- XML Tracking Data Message: Schema updated to reflect above changes.
- Use of the SANA Registry as the source of the values associated with the ORIGINATOR, TIME_SYSTEM, and REFERENCE_FRAME keywords.

The test of the TDM will exercise the following data types:
- Doppler Counts: See Test Case #1
- Phase Counts: See Test Case #2
- Optical Magnitude: See Test Case #3
- Radar Cross Section: See Test Case #4
- XML Tracking Data Message: See Test Case #5
- SANA Registries:
  - Organizations (https://sanaregistry.org/r/organizations),
  - Time Systems (https://sanaregistry.org/r/time_systems), and
  - Celestial Body Reference Frames (https://sanaregistry.org/r/celestial_body_reference_frames).

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

Test#	Spacecraft	Agencies, Direction	Data Types
1	TBDAQUA	NASA/GSFC => AGI	Doppler Counts
2	MEX	ESOC<=>GMV DSN=>JPL Navigation	Phase Counts
3	Titan IIIC transtage debris	ESA <=> DLR ESA internal	Optical Magnitude
4	AVUM rocket body	ESA => NASA/JPLDLR ESA internal	Radar Cross Section
5	TBD	NASA/JPL => ESA/ESOC	XML TDM

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 are presented.

Note: initially it was thought that a test of the new DATA_TYPES and TRACK_ID keyword keywords would be necessary, however, given that itthese effectively functions as a

"COMMENT" statements, the Working Group determined that no testing would be required. TDM processing will be the same regardless of whether or not this keyword is present. The new CORRECTION_ABERRATION_* keywords are conceptually identical to the existing set of CORRECTION_* metadata keywords and are thus tested by analogy.

4.2 TEST PLAN DETAILS

4.2.1 TEST CASE #1: DOPPLER COUNTS

For this test case, NASA/GSFC Flight Dynamics Facility will send TDMs to AGI that contain the metadata and data keywords relevant to Doppler represented as counts for the AQUA spacecraft. The counts will 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 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.

AGI will process the CCSDS TDMs with their system and provide a file with time delimited Doppler conversion to Hertz . 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 a 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 for verification.

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

4.2.2 TEST CASE #2: PHASE COUNTS

Part 1: For this test case, ESA/ESOC will provide a number of files (e.g. from MEX) containing phase count data. These are actual files that are used in the MEX orbit determination process. The test case is implemented in two steps:

- The input files are converted to TDM.

    In this process the mapping between the data elements in the input file are mapped into the data elements provided by the TDM. The main purpose is to ensure that the information required for the processing of the phase count data can be conveyed by the definition of the TDM for phase count data.

In the next step it is important to verify that the data provided by the TDM is sufficient to support the orbit determination process as if the original input files were given. Note however, that it is not the purpose of the test to fully reconstruct the original input files.

In the process both XML and KVN files will be generated.

- XML files mainly to verify the completeness and consistency of the generated TDM.

- KVN to be provided to ESOC's flight dynamics team for the ~~implementation~~ analysis of the second step described above.

Part 2: The NASA/DSN will prepare a test TDM(s) containing both TRANSMIT_PHASE data and RECEIVE_PHASE data. The TDM(s) will be provided to the JPL navigation section for processing (note: this is a current operational TDM transmission path for some missions DSN=>JPL Nav=>mission team). JPL Navigation will process the provided TDM and compare the results to a TDM prepared using TRANSMIT_FREQ and RECEIVE_FREQ data.

Expected Results

Part 1: ESA's IFMS phase count data is converted successfully to TDM format (both KVN and XML), and the TDM content is sufficient for use in orbit determination.

Part 2: JPL comparison of the phase and frequency TDM data provides commensurate results.

4.2.3 TEST CASE #3: 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 DLR/GSOC. The TDMs will contain the TIME_SYSTEM, START_TIME, STOP_TIME, PARTICIPANT_1, PARTICPANT_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 DLR/GSOC 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.~~

Expected Results

It is anticipated that both the ESA/ESOC and DLR/GSOC prototypes 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.

4.2.4   TEST CASE #4: RADAR CROSS SECTION

For this test case, ESA/ESOC will provide a number of KVN TDMs containing RCS, azimuth, elevation, range, and Doppler for an AVUM Rocket Body (2012-006K) to NASA/JPL. The TDMs will contain the TIME_SYSTEM, START_TIME, STOP_TIME, PARTICIPANT_1, PARTICPANT_2, MODE, PATH, TIMETAG_REF, INTEGRATION_INTERVAL, INTEGRATION_REF, RANGE_MODULUS, RANGE_UNITS, and ANGLE_TYPE keywords in the metadata sections, and the ANGLE_1, ANGLE_2, RANGE, DOPPLER_INSTANT~~EAN~~EOUS, and RCS keywords in the data sections. Both ESA/ESOC and ~~NASA/JPL~~DLR/GSOC 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~~DLR/GSOC prototype~~s~~ 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.

4.2.5   TEST CASE #5: XML TRACKING DATA MESSAGE

Premise #1: Prototype Test Cases #1 through #4 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 #5 must occur after Test Cases #1 through #4 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 #4, 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 #4 (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.

5   TRACKING DATA MESSAGE TEST REPORT

5.1   TEST RESULTS OVERVIEW

Engineers at the 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 MOIMS Area Director, the CCSDS Engineering Steering Group (CESG), and the CCSDS Management Council (CMC), along with results of the Agency Reviews. At that timeAssuming successful CESG and CMC "approval to publish" polls, a formal request will be submitted to the CMC for progression of the TDM will proceed 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.

5.2   TEST RESULTS DETAIL

In the remainder of this document, the detailed test data sheets from the TDM V.2 Prototype Testing will be presented.

5.2.1 TEST CASE #1: DOPPLER COUNTS

TRACKING DATA MESSAGE PROTOTYPE TEST DATA SHEET

1	Test Case Number:	1
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:
67	Test Engineer:	TDM Generation: TDM Processing:
78	Spacecraft:	
89	Tracking Data Types:	
910	Tracking Data Date/Time Range:	
1011	Variances from Expected Results:	
1112	Results (Pass, Partial Pass, Fail):	
1213	Comments:	

5.2.2   TEST CASE #2: PHASE COUNTS

TRACKING DATA MESSAGE PROTOTYPE TEST DATA SHEET
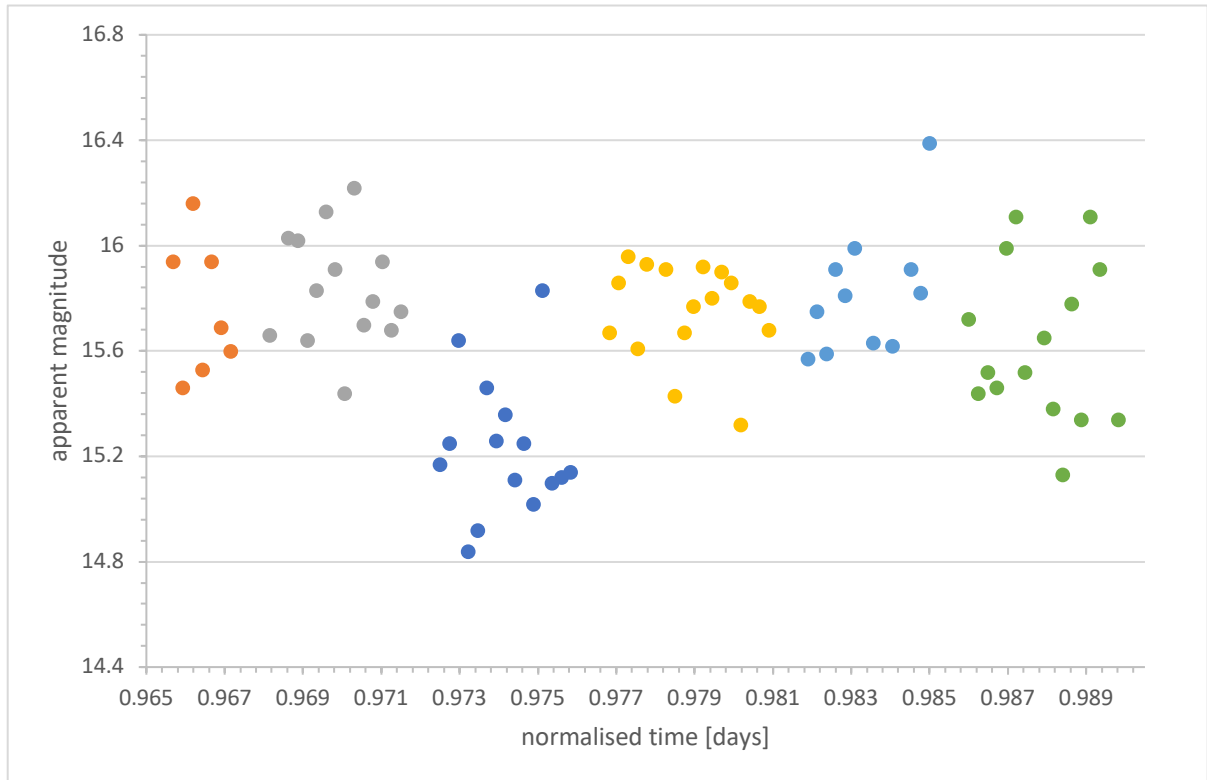
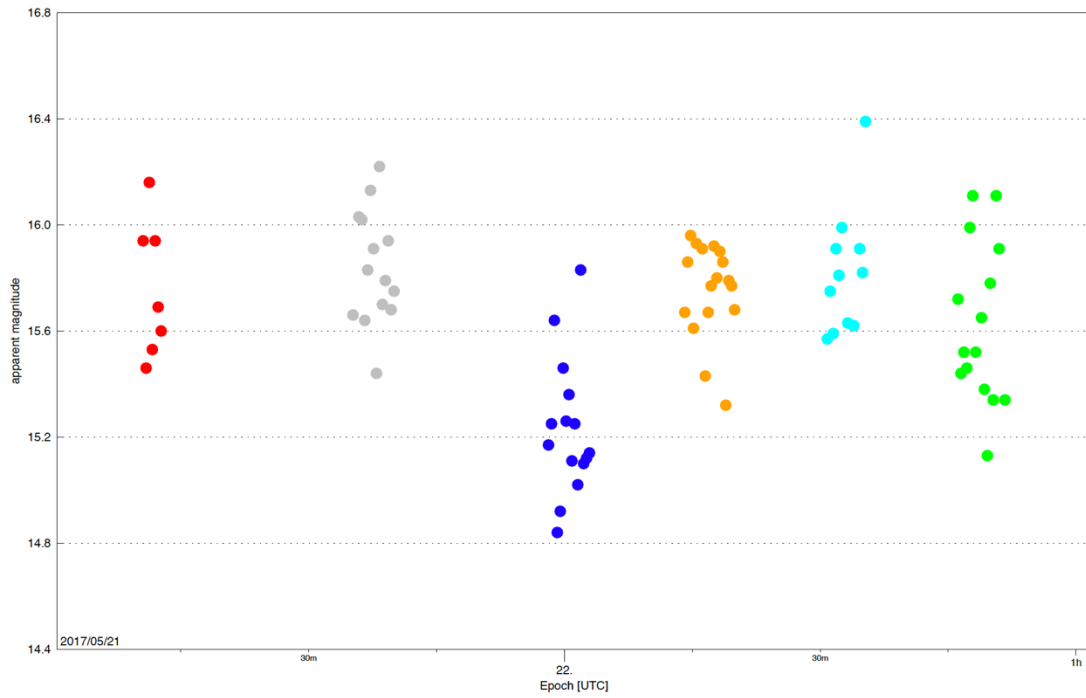| 1	Test Case Number:	2
2	Report Date:	09-May-2019
3	Program Under Test:	Tracking Data Message V2 (TDM) Prototype
4	Agencies Participating in this Test Case:	ESA/ESOC GMV
5	Agency Responsible for Prototype:	TDM Generation: TDM Processing:
~~6~~	~~Prototype Version #~~ ~~(if applicable):~~	~~TDM Generation: N/A~~ ~~TDM Processing: N/A~~
6~~7~~	Test Engineer:	TDM Generation: Fran Martinez TDM Processing/Analysis: Frank Budnik
7~~8~~	Spacecraft:	Mars Express (MEX)
8~~9~~	Tracking Data Types:	TRANSMIT_FREQ, RECEIVE_PHASE_CT
9~~10~~	Tracking Data Date/Time Range:	2018-08-09T16:19:13.000000 2018-08-09T19:12:21.000000
10~~11~~	Variances from Expected Results:	The outcome of the test is in my view Partially Passed. There is no field in the TDM to convey the coherency of the Doppler. Only for range measurements the RANGE_MODE keyword is defined. For the purpose of the test, RANGE_MODE has been used for similarity in the contents of the field but it formally is a misuse of the standard. If the same type of field is required for Doppler we have to extend the TDM or modify the RANGE_MODE keyword or its definition (or both).
11~~12~~	Results (Pass, Partial Pass, Fail):	Partial Pass
12~~13~~	Comments:	The initially intended step where ESOC would ingest the TDM file in their software has been replaced by the analysis of the TDM generated files to ensure that they convey the required information for orbit determination. Although this is a modification on the initial approach I think it is still valid for the purpose of the test. TDM Analysis has confirmed that the data is sufficient for orbit determination.

5.2.3 TEST CASE #3: OPTICAL MAGNITUDE

TRACKING DATA MESSAGE PROTOTYPE TEST DATA SHEET

1	Test Case Number:	3
2	Report Date:	TBC
3	Program Under Test:	Tracking Data Message V2 (TDM) Prototype
4	Agencies Participating in this Test Case:	ESA/ESOC DLR/GSOC
5	Agency Responsible for Prototype:	TDM Generation: ESA/ESOC TDM Processing: ESA/ESOC, DLR/GSOC
6	Prototype Version # (if applicable):	TDM Generation: ESA/ESOC: n/a TDM Processing: ESA/ESOC: n/a
67	Test Engineer:	TDM Generation: Alexandru Mancas TDM Processing: Alexandru Mancas, Agent XRalph Kahle
78	Spacecraft:	TITAN 3C TRANSTAGE DEBRIS
89	Tracking Data Types:	ANGLE_1, ANGLE_2, MAG
910	Tracking Data Date/Time Range:	2017-05-21T23:10:35.310 2017-05-22T00:51:41.610
1011	Variances from Expected Results:	???
1112	Results (Pass, Partial Pass, Fail):	???
1213	Comments:	DLR/GSOC finalized TDM v2 prototyping and we are able to read and process the six TDM files provided by ESA. The DLR plot on TEST CASE #3: OPTICAL MAGNITUDE, looks pretty similar to the one provided by ESA.

*** TO DO *** Resolve Ralph's question: Alexandru, you may check the x-axis in your plot (normalized time [days]): when we normalize time, we get a 1.000 for the middle of the dark blue data. Maybe you make use of a different reference time?

Test Case #3: ESA Results. NOTE: Each color is from a different TDM segment.

Test Case #3: DLR Results. NOTE: Each color is from a different TDM segment.

5.2.4 TEST CASE #4: RADAR CROSS SECTION

TRACKING DATA MESSAGE PROTOTYPE TEST DATA SHEET

1	Test Case Number:	4
2	Report Date:	TBC
3	Program Under Test:	Tracking Data Message V2 (TDM) Prototype
4	Agencies Participating in this Test Case:	ESA/ESOC ~~JPL~~DLR
5	Agency Responsible for Prototype:	TDM Generation: ESA/ESOC TDM Processing: ESA/ESOC, ~~JPL~~DLR
~~6~~	~~Prototype Version # (if applicable):~~	~~TDM Generation: ESA/ESOC: n/a~~ ~~TDM Processing: ESA/ESOC: n/a~~
6~~7~~	Test Engineer:	TDM Generation: Alexandru Mancas TDM Processing: Alexandru Mancas, ~~JPL~~ DLR engineer
7~~8~~	Spacecraft:	AVUM R/B (2012-006K)
8~~9~~	Tracking Data Types:	ANGLE_1, ANGLE_2, RANGE, DOPPLER_INSTANTANEOUS, RCS
9~~10~~	Tracking Data Date/Time Range:	2016-10-27T11:54:20.897308 2016-10-27T11:59:27.153196
10~~11~~	Variances from Expected Results:	???
11~~12~~	Results (Pass, Partial Pass, Fail):	???
12~~13~~	Comments:	
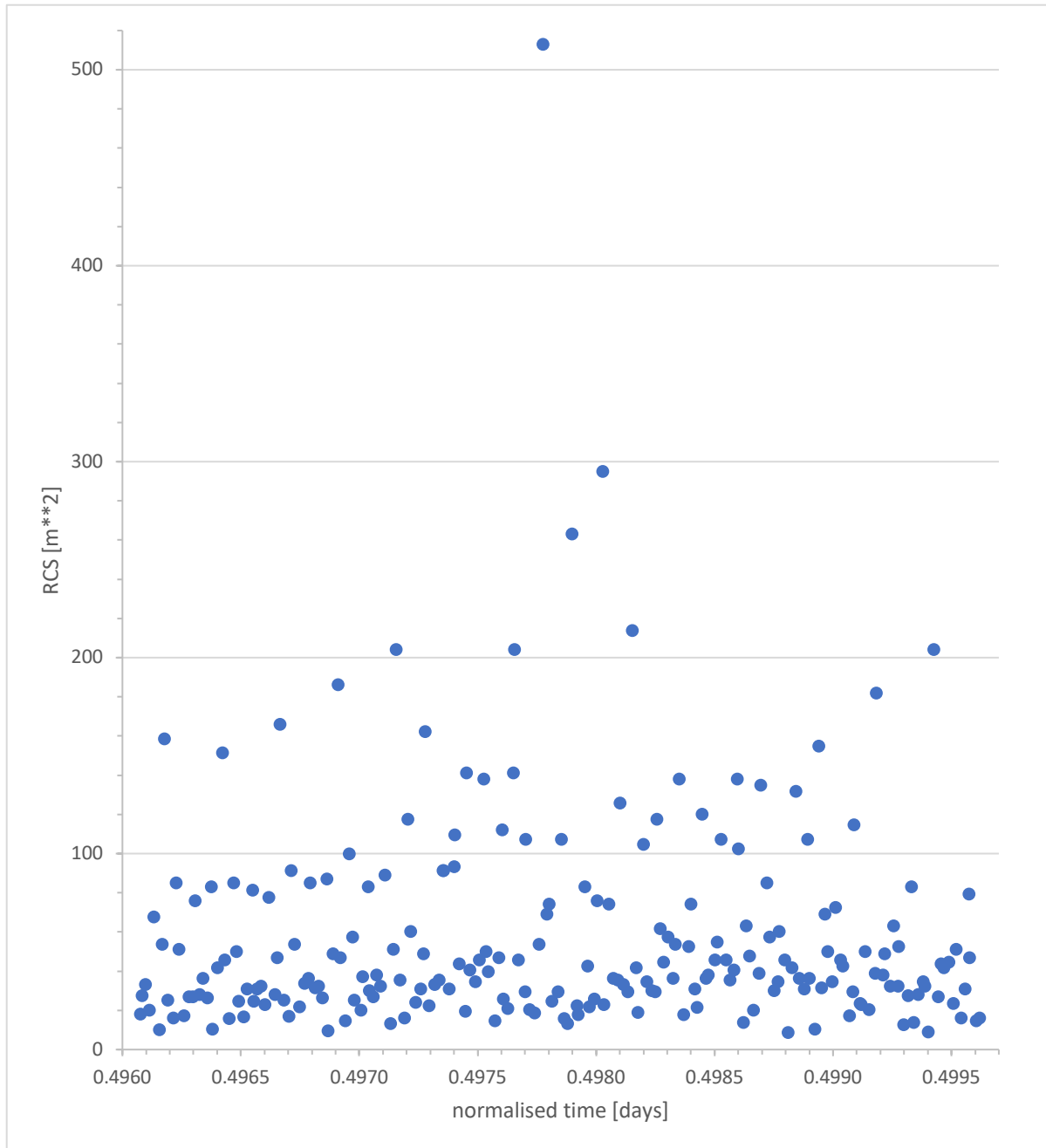
5.2.5 TEST CASE #5: XML TRACKING DATA MESSAGE

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

ANNEX A

TRACKING DATA MESSAGE PROTOTYPE TEST DATA SHEET

SAMPLE

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:~~
6~~7~~	Test Engineer:	TDM Generation: TDM Processing:
7~~8~~	Spacecraft:	
8~~9~~	Tracking Data Types:	
9~~10~~	Tracking Data Date/Time Range:	
10~~11~~	Variances from Expected Results:	
11~~12~~	Results (Pass, Partial Pass, Fail):	
12~~13~~	Comments:	

ANNEX B

ACRONYMS

| CCSDS | Consultative Committee for Space Data Systems |
| ESA | |

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

DSN   Deep Space Network

ESA   European Space Agency

ESOC   European Space Operations Center

GSFC   Goddard Space Flight Center

GSOC   German Space Operations Center

JPL   Jet Propulsion Laboratory

NASA   National Aeronautics and Space Administration

RID   Review Item Discrepancy

TDM   Tracking Data Message

XML   eXtensible Markup Language