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Space data and information transfer systems — Tracking data message

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Space data and information transfer systems — Tracking data message

*Systèmes de transfert des informations et données spatiales —
Message de données de suivi*



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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13526 was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 503.0-B-1, November 2007) and was adopted (without modifications except those stated in Clause 2 of this International Standard) by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 13, *Space data and information transfer systems*.

BS ISO 13526:2010+A1:2015
ISO 13526:2010+A1:2015(E)

Space data and information transfer systems — Tracking data message

1 Scope

This International Standard specifies a standard message format for use in exchanging spacecraft tracking data between space agencies. Such exchanges are used for distributing tracking data output from routine interagency cross-supports, in which spacecraft missions managed by one agency are tracked from a ground station managed by a second agency. The standardization of tracking data formats facilitates space agency allocation of tracking sessions to alternate tracking resources.

This International Standard includes requirements and criteria that the message format has been designed to meet. For exchanges where these requirements do not capture the needs of the participating agencies, another mechanism can be selected.

The scope and field of application are furthermore detailed in subclause 1.2 of the enclosed CCSDS publication.

2 Requirements

Requirements are the technical recommendations made in the following publication (reproduced on the following pages), which is adopted as an International Standard:

CCSDS 503.0-B-1, November 2007, *Tracking data message*

For the purposes of international standardization, the modifications outlined below shall apply to the specific clauses and paragraphs of publication CCSDS 503.0-B-1.

Pages i to v

This part is information which is relevant to the CCSDS publication only.

Page 1-4

Add the following information to the reference indicated:

[3] Document CCSDS 301.0-B-3, January 2002, is equivalent to ISO 11104:2003.

[4] Document CCSDS 502.0-B-1, September 2004, is equivalent to ISO 22644:2006.

Page E-1

Add the following information to the reference indicated:

[E2] Document CCSDS 501.0-B-1-S, January 1987, is equivalent to ISO 11103:1991¹⁾.

1) Withdrawn in 2007.

3 Revision of publication CCSDS 503.0-B-1

It has been agreed with the Consultative Committee for Space Data Systems that Subcommittee ISO/TC 20/SC 13 will be consulted in the event of any revision or amendment of publication CCSDS 503.0-B-1. To this end, NASA will act as a liaison body between CCSDS and ISO.



Recommendation for Space Data System Standards

TRACKING DATA MESSAGE

RECOMMENDED STANDARD

CCSDS 503.0-B-1

BLUE BOOK
November 2007

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CCSDS RECOMMENDED STANDARD FOR TRACKING DATA MESSAGE

AUTHORITY

Issue:	Recommended Standard, Issue 1
Date:	November 2007
Location:	Washington, DC, USA

This document has been approved for publication by the Management Council of the Consultative Committee for Space Data Systems (CCSDS) and represents the consensus technical agreement of the participating CCSDS Member Agencies. The procedure for review and authorization of CCSDS Recommendations is detailed in the *Procedures Manual for the Consultative Committee for Space Data Systems*, and the record of Agency participation in the authorization of this document can be obtained from the CCSDS Secretariat at the address below.

This document is published and maintained by:

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CCSDS RECOMMENDED STANDARD FOR TRACKING DATA MESSAGE

STATEMENT OF INTENT

The Consultative Committee for Space Data Systems (CCSDS) is an organization officially established by the management of its members. The Committee meets periodically to address data systems problems that are common to all participants, and to formulate sound technical solutions to these problems. Inasmuch as participation in the CCSDS is completely voluntary, the results of Committee actions are termed **Recommended Standards** and are not considered binding on any Agency.

This **Recommended Standard** is issued by, and represents the consensus of, the CCSDS members. Endorsement of this **Recommendation** is entirely voluntary. Endorsement, however, indicates the following understandings:

- o Whenever a member establishes a CCSDS-related **standard**, this **standard** will be in accord with the relevant **Recommended Standard**. Establishing such a **standard** does not preclude other provisions which a member may develop.
- o Whenever a member establishes a CCSDS-related **standard**, that member will provide other CCSDS members with the following information:
 - The **standard** itself.
 - The anticipated date of initial operational capability.
 - The anticipated duration of operational service.
- o Specific service arrangements shall be made via memoranda of agreement. Neither this **Recommended Standard** nor any ensuing **standard** is a substitute for a memorandum of agreement.

No later than five years from its date of issuance, this **Recommended Standard** will be reviewed by the CCSDS to determine whether it should: (1) remain in effect without change; (2) be changed to reflect the impact of new technologies, new requirements, or new directions; or (3) be retired or canceled.

In those instances when a new version of a **Recommended Standard** is issued, existing CCSDS-related member standards and implementations are not negated or deemed to be non-CCSDS compatible. It is the responsibility of each member to determine when such standards or implementations are to be modified. Each member is, however, strongly encouraged to direct planning for its new standards and implementations towards the later version of the Recommended Standard.

CCSDS RECOMMENDED STANDARD FOR TRACKING DATA MESSAGE

FOREWORD

This document is a Recommended Standard for tracking data messages and has been prepared by the Consultative Committee for Space Data Systems (CCSDS). The tracking data message described in this Recommended Standard is the baseline concept for tracking data interchange applications that are cross-supported between Agencies of the CCSDS.

This Recommended Standard establishes a common framework and provides a common basis for the format of tracking data exchange between space agencies. It allows implementing organizations within each Agency to proceed coherently with the development of compatible derived standards for the flight and ground systems that are within their cognizance. Derived Agency standards may implement only a subset of the optional features allowed by the Recommended Standard and may incorporate features not addressed by this Recommended Standard.

Through the process of normal evolution, it is expected that expansion, deletion or modification to this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, as defined in the *Procedures Manual for the Consultative Committee for Space Data Systems*. Current versions of CCSDS documents are maintained at the CCSDS Web site:

<http://www.ccsds.org/>

Questions relating to the contents or status of this document should be addressed to the CCSDS Secretariat at the address indicated on page i.

CCSDS RECOMMENDED STANDARD FOR TRACKING DATA MESSAGE

At time of publication, the active Member and Observer Agencies of the CCSDS were:

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- Japan Aerospace Exploration Agency (JAXA)/Japan.
- National Aeronautics and Space Administration (NASA)/USA.

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- Austrian Space Agency (ASA)/Austria.
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CCSDS RECOMMENDED STANDARD FOR TRACKING DATA MESSAGE

DOCUMENT CONTROL

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CCSDS RECOMMENDED STANDARD FOR TRACKING DATA MESSAGE

1 INTRODUCTION

1.1 PURPOSE

1.1.1 This Tracking Data Message (TDM) Recommended Standard specifies a standard message format for use in exchanging spacecraft tracking data between space agencies. Such exchanges are used for distributing tracking data output from routine interagency cross-supports in which spacecraft missions managed by one agency are tracked from a ground station managed by a second agency. The standardization of tracking data formats facilitates space agency allocation of tracking sessions to alternate tracking resources. This Recommended Standard has been developed via consensus of the Navigation Working Group of the CCSDS Mission Operations and Information Management Services (MOIMS) area.

1.1.2 This document includes requirements and criteria that the message format has been designed to meet. For exchanges where these requirements do not capture the needs of the participating Agencies another mechanism may be selected.

1.2 SCOPE AND APPLICABILITY

1.2.1 This Recommended Standard contains the specification for a Tracking Data Message designed for applications involving tracking data interchange between space data systems. Tracking data includes data types such as Doppler, transmit/received frequencies, range, angles, Delta-DOR, DORIS, PRARE, media correction, weather, etc. The rationale behind the design of the message is described in annex F and may help the application engineer construct a suitable message. It is acknowledged that this version of the Recommended Standard may not apply to every single tracking session or data type; however, it is desired to focus on covering approximately the '95% level' of tracking scenarios, and to expand the coverage in future versions as experience with the TDM is gained.

1.2.2 This message is suited to inter-agency exchanges that involve automated interaction. The attributes of a TDM make it primarily suitable for use in computer-to-computer communication because of the large amount of data typically present. The TDM is self-contained, with no additional information required beyond that specified in an Interface Control Document (ICD) written jointly by the service provider and customer agency.

1.2.3 Definition of the accuracy pertaining to any particular TDM is outside the scope of this Recommended Standard and should be specified via an Interface Control Document (ICD) between data exchange participants.

1.2.4 This Recommended Standard is applicable only to the message format and content, but not to its transmission. The method of transmitting the message between exchange partners is beyond the scope of this document and should be specified in the ICD. Message transmission could be based on a CCSDS data transfer protocol, file based transfer protocol such as SFTP, stream-oriented media, or other secure transmission mechanism. In general, the transmission mechanism must not place constraints on the technical data content of a TDM.

1.2.5 There are some specific exclusions to the TDM, as listed below:

1.2.5.1 Satellite Laser Ranging (SLR) ‘Fullrate’ and/or ‘Normal Points’ format (sometimes referred to as ‘Quicklook’), which are already transferred via a standardized format documented at <http://ilrs.gsfc.nasa.gov/>;

1.2.5.2 Exchanges of raw Global Navigation Satellite System (GNSS) data, which is standardized via the RINEX format (<http://gps.wva.net/html.common/rinex.html>);

1.2.5.3 Global Positioning Satellite (GPS) navigation solutions, which are standardized via the SP3 format (<http://www.ngs.noaa.gov/GPS/GPS.html>);¹

1.2.5.4 Optical data from navigation cameras (pixel based, row-column, etc.);

1.2.5.5 LIDAR data (which may include a laser range finder); however, such data could conceivably be transferred via TDM with a ‘RANGE’ keyword (see 3.5.2.6); and

1.2.5.6 Altimeter data; however, such data could conceivably be transferred via TDM with a ‘RANGE’ keyword (see 3.5.2.6).

1.2.6 Description of the message format based on the use of eXtensible Markup Language (XML) is detailed in an integrated XML schema document for all Navigation Data Message Recommendations: Attitude Data Messages (ADM), Orbit Data Messages (ODM), and Tracking Data Message (TDM). See reference [E8].

1.3 CONVENTIONS AND DEFINITIONS

1.3.1 Conventions and definitions of navigation concepts such as reference frames, time systems, etc., are provided in reference [1].

1.3.2 The following conventions apply throughout this Recommended Standard:

- the words ‘shall’ and ‘must’ imply a binding and verifiable specification;
- the word ‘should’ implies an optional, but desirable, specification;
- the word ‘may’ implies an optional specification;
- the words ‘is’, ‘are’, and ‘will’ imply statements of fact.

¹ It has been suggested that the statement regarding navigation solutions being standardized by SP3 is not correct, because SP3 prescribes equidistant data (ephemerides), which are in general not provided by each GPS/GNSS receiver. It was proposed that the navigation solution data (epoch, x , y , z , v_x , v_y , v_z) should be provided in the TDM, with the velocities as optional values. However, this would require major changes to the TDM that are contrary to its intended purpose. As an alternative, the CCSDS Orbit Data Messages OEM (Orbit Ephemeris Message) (reference [4]) could be used to convey the navigation solution if all position and velocity components are transferred. The OEM is already set up to convey all the required values, and can be used to convey orbit reconstructions as well as orbit predictions.

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- The word ‘participant’ denotes an entity that has the ability to acquire or broadcast navigation messages and/or radio frequencies, for example, a spacecraft, a quasar, a tracking station, a tracking instrument, or an agency.
- The term ‘n/a’ or ‘N/A’ denotes an attribute that is not applicable or not available.

1.3.3 The following conventions for unit notations apply throughout this Recommended Standard. Insofar as possible, an effort has been made to use units that are part of the International System of Units (SI Units); units are either SI base units, SI derived units, or units outside the SI that are accepted for use with the SI (see reference [8]). There are a small number of specific cases where units that are more widely used in the navigation community are specified, but every effort has been made to minimize these departures from the SI.

%:	per cent
dBHz:	decibels referenced to one Hz
dBW:	decibels referenced to one Watt
deg:	degrees of plane angle
hPa:	hectoPascal
Hz:	Hertz
K:	degrees Kelvin
km:	kilometers
m:	meters
RU:	range units
s:	seconds
TECU:	Total Electron Count Units

1.4 STRUCTURE OF THIS DOCUMENT

1.4.1 Section 2 provides a brief overview of the CCSDS-recommended Tracking Data Message (TDM).

1.4.2 Section 3 provides details about the structure and content of the TDM.

1.4.3 Section 4 provides details about the syntax used in the TDM.

1.4.4 Section 5 discusses security considerations for the TDM.

1.4.5 Annex A provides a normative list of approved values for selected TDM Metadata Section keywords.

1.4.6 Annex B lists a number of items that should be covered in interagency ICDs prior to exchanging TDMs on a regular basis. There are several statements throughout the document that refer to the desirability or necessity of such a document; this annex consolidates all the suggested ICD items in a single list.

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1.4.7 Annex C is a list of abbreviations and acronyms applicable to the TDM.

1.4.8 Annex D shows how various tracking scenarios can be accommodated using the TDM, via several examples.

1.4.9 Annex E contains a list of informative references.

1.4.10 Annex F lists a set of requirements and desirable characteristics that were taken into consideration in the design of the TDM.

1.4.11 Annex G provides a TDM Summary Sheet, or ‘Quick Reference’.

1.5 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommended Standard. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommended Standard are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS Recommended Standards.

- [1] *Navigation Data—Definitions and Conventions*. Report Concerning Space Data System Standards, CCSDS 500.0-G-2. Green Book. Issue 2. Washington, D.C.: CCSDS, November 2005.
- [2] *Information Technology—8-Bit Single-Byte Coded Graphic Character Sets—Part 1: Latin Alphabet No. 1*. International Standard, ISO/IEC 8859-1:1998. Geneva: ISO, 1998.
- [3] *Time Code Formats*. Recommendation for Space Data System Standards, CCSDS 301.0-B-3. Blue Book. Issue 3. Washington, D.C.: CCSDS, January 2002.
- [4] *Orbit Data Messages*. Recommendation for Space Data System Standards, CCSDS 502.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2004.
- [5] *Spacewarn Bulletin*. Greenbelt, MD, USA: WDC-SI. <<http://nssdc.gsfc.nasa.gov/spacewarn>>
- [6] *XML Schema Part 2: Datatypes*. 2nd ed. P. Biron and A. Malhotra, eds. W3C Recommendation 28. n.p.: W3C, 2004.
- [7] *IEEE Standard for Binary Floating-Point Arithmetic*. IEEE Std 754-1985. New York: IEEE, 1985.
- [8] “The NIST Reference on Constants, Units, and Uncertainty.” NIST Physics Laboratory. <<http://physics.nist.gov/cuu/index.html>>

NOTE – Informative references are provided in annex E.

2 OVERVIEW

2.1 GENERAL

This section provides a high-level overview of the CCSDS recommended Tracking Data Message, a message format designed to facilitate standardized exchange of spacecraft tracking data between space agencies.

2.2 THE TRACKING DATA MESSAGE (TDM) BASIC CONTENT

2.2.1 The TDM is realized as a sequence of plain ASCII text lines (reference [2]), which may be in either a file format or a real-time stream. The content is separated into three basic types of computer data structure as described in section 3. The TDM architecture takes into account that some aspects of tracking data change on a measurement-by-measurement basis (data); some aspects change less frequently, but perhaps several times per track (metadata); and other aspects change only rarely, e.g., once per track or perhaps less frequently (header). The TDM makes it possible to convey a variety of tracking data used in the orbit determination process in a single data message (e.g., standard Doppler and range radiometrics in a variety of tracking modes, VLBI data, antenna pointing angles, etc.). To aid in precision trajectory modeling, additional ancillary information may be included within a TDM if it is desired and/or available (e.g., media corrections, meteorological data, clock data, and other ancillary data). Facilities for documenting comments are provided.

2.2.2 The Tracking Data Message in this version of the Recommended Standard is ASCII-text formatted. While binary-based tracking data message formats are computer efficient and minimize overhead during data transfer, there are ground-segment applications for which an ASCII character-based message is more appropriate. For example, ASCII format character-based tracking data representations are useful in transferring data between heterogeneous computing systems, because the ASCII character set is nearly universally used and is interpretable by all popular systems. In addition, direct human-readable dumps of text to displays, emails, documents or printers are possible without preprocessing. The penalty for this convenience is some measure of inefficiency (based on early tests, such penalty would be greatly reduced if the data is compressed for transmission).

2.2.3 The ASCII text in a TDM can be exchanged in either of two formats: a 'keyword-value notation' format (KVN) or an XML format. The KVN formatted TDM is described in this document. Description of the message format based on XML is detailed in an integrated XML schema document for all Navigation Data Messages (reference [E8]). Exchange participants should specify in the ICD which TDM ASCII format will be exchanged, the KVN or the XML format.

2.2.4 Normally a TDM will contain tracking data for a single spacecraft participant, unless the tracking session is spacecraft-to-spacecraft in nature. If a tracking operation involves information from multiple spacecraft participants tracked from the ground, the data may be included in a single TDM by using multiple segments (see 3.1); or multiple TDMs may be used, one per spacecraft participant.

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2.2.5 For a given spacecraft participant, multiple tracking data messages may be provided in a message exchange session to achieve the tracking data requirements of the participating agencies (e.g., launch supports with periodically delivered TDMs, or other critical events such as maneuvers, encounters, etc.).

2.2.6 Provisions for the frequency of exchange and special types of exchanges should be specified in an ICD.

CCSDS RECOMMENDED STANDARD FOR TRACKING DATA MESSAGE

3 TRACKING DATA MESSAGE STRUCTURE AND CONTENT

3.1 GENERAL

3.1.1 The TDM shall consist of digital data represented as ASCII text lines (see reference [2]) in KVN format (Keyword = Value Notation—see section 4). The lines constituting a TDM shall be represented as a combination of:

- a) a Header (see 3.2);
- b) a Metadata Section (data about data) (see 3.3); and
- c) a Data Section (tracking data represented as ‘Tracking Data Records’) (see 3.4).

Optional comments may appear in specified locations in the Header, Metadata, and Data Sections (see 4.5).

3.1.2 Taken together, the Metadata Section and its associated Data Section shall be called a TDM Segment.

3.1.3 Each TDM shall have a Header and a Body. The TDM Body shall consist of one or more TDM Segments. There shall be no limit to the number of Segments in a given TDM Body, beyond practical constraints, as shown in table 3-1. Each Segment shall consist of a Metadata Section and a Data Section that consists of a minimum of one Tracking Data Record. Therefore, the overall structure of the TDM shall be:

- $\text{TDM} = \text{Header} + \text{Body};$
- $\text{Body} = \text{Segment} [+ \text{Segment} + \dots + \text{Segment}];$
- $\text{Segment} = \text{Metadata Section} + \text{Data Section};$
- $\text{Data Section} = \text{Tracking Data Record (TDR)} [+ \text{TDR} + \text{TDR} \dots + \text{TDR}].$

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Table 3-1: TDM Structure

Item			Obligatory?
Header			Yes
Body	Segment 1	Metadata 1	Yes
		Data 1	
	Segment 2	Metadata 2	No
		Data 2	
	.	.	.
	.	.	.
	.	.	.
	Segment n	Metadata n	No
		Data n	

3.1.4 The TDM shall consist of tracking data for one or more tracking participants at multiple epochs contained within a specified time range. (Note that the term ‘participant’ applies equally to spacecraft, quasars, tracking stations, and agency centers, as discussed in reference [1]. Thus there may exist Tracking Data Messages for which there is no applicable spacecraft.) Generally, but not necessarily, the time range of a TDM may correspond to a ‘tracking pass’.

3.1.5 The TDM shall be easily readable by both humans and computers.

3.1.6 It shall be possible to exchange a TDM either as a real-time stream or as a file.

3.1.7 The TDM file naming scheme shall be agreed to on a case-by-case basis between the participating agencies, typically specified in an ICD. In general, the file name syntax and length must not violate computer constraints for those computing environments in use by Member Agencies for processing tracking data.

3.1.8 The method of exchanging TDMs shall be decided on a case-by-case basis by the participating agencies and documented in an ICD. The exchange method shall not constrain the tracking data content.

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3.2 TDM HEADER

3.2.1 The TDM shall include a Header that consists of information that identifies the basic parameters of the message. The first Header line must be the first non-blank line in the message.

3.2.2 A description of TDM Header items and values is provided in table 3-2, which specifies for each item:

- the keyword to be used;
- a short description of the item;
- examples of allowed values; and
- whether the item is obligatory or not obligatory.

3.2.3 Only those keywords shown in table 3-2 shall be used in a TDM Header. The order of occurrence of the obligatory and optional KVN assignments shall be fixed as shown in table 3-2.

Table 3-2: TDM Header

Keyword	Description	Examples	Obligatory
CCSDS_TDM_VERS	Format version in the form of 'x.y', where 'y' shall be incremented for corrections and minor changes, and 'x' shall be incremented for major changes.	0.12 (for testing) 1.0	Yes
COMMENT	See 4.5.	COMMENT This is a comment	No
CREATION_DATE	Data creation date/time in UTC. For format specification, see 4.3.9.	2001-11-06T11:17:33 2002-204T15:56:23.4 2006-001T00:00:00Z	Yes
ORIGINATOR	Creating agency. Value should be specified in the ICD.	CNES, ESOC, GSFC, GSOC, JPL, JAXA, etc.	Yes

3.2.4 Each line in the TDM Header, with the exception of COMMENTS, shall have the following generic format:

keyword = value

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3.2.5 The TDM Header shall provide a CCSDS Tracking Data Message version number that identifies the format version; this is included to anticipate future changes and to provide the ability to extend the standard with no disruption to existing users. The version keyword is `CCSDS_TDM_VERS` and the value shall have the form of $x.y$ where y is incremented for corrections and minor changes, and x is incremented for major changes. Version 1.0 shall be reserved for the initial version accepted by the CCSDS as an official Recommended Standard ('Blue Book'). Interagency testing of TDMs shall be conducted using version numbers less than 1.0 (e.g., '0.y'). Specific TDM versions that will be exchanged between agencies should be documented via the ICD.

3.2.6 The TDM Header shall include the `CREATION_DATE` keyword with the value set to the Coordinated Universal Time (UTC) when the data was created (file creation time if in file format, or first data point in stream), as specified in reference [3] (ASCII Time Code A or B).

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3.3 TDM METADATA

3.3.1 GENERAL

3.3.1.1 The TDM shall include at least one Metadata Section that contains configuration details (metadata) applicable to the Data Section in the same TDM Segment. The information in the Metadata Section aligns with the tracking data to provide descriptive information (typically, the metadata is the type of information that does not change frequently during a tracking session).

3.3.1.2 Each line in the TDM Metadata Section, with the exception of COMMENTS, shall have the following generic format:

keyword = value

3.3.1.3 A single TDM Metadata Section shall precede each Data Section.

3.3.1.4 When there are changes in the values assigned to any of the keywords in the Metadata Section, a new Segment must be started (e.g., mode change from one-way to two-way tracking).

3.3.1.5 The first and last lines of a TDM Metadata Section shall consist of the META_START and META_STOP keywords, respectively. These keywords are used to facilitate parsing.

3.3.1.6 Table 3-3 specifies for each Metadata item:

- the keyword to be used;
- a short description of the item;
- a list of required values or examples of allowed values; and
- whether the item is obligatory or not obligatory.

The column marked ‘N/E’ will contain an ‘N’ if the column marked ‘Normative Values / Examples’ contains normative values, and will contain an ‘E’ if the column contains example values that are non-normative. For normative values, a fully enumerated set of values may be provided, or the contents of table 3-3 may be a sample of values that are fully enumerated in an annex. In this latter case, the necessary annex is identified.

3.3.1.7 Only those keywords shown in table 3-3 shall be used in a TDM Metadata Section. Obligatory items shall appear in every TDM Metadata Section. Items that are not obligatory may or may not appear in any given TDM Metadata Section, at the discretion of the data producer, based on the requirements of the data and its intended application (see annex G for a TDM Summary Sheet that illustrates the relationships between data types and metadata). For most metadata keywords there is no default value; where there is a default value, it is

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specified at the end of the 'Description' section for the given keyword. If a keyword is not present in a TDM, and a default value is defined, the default shall be assumed.

3.3.1.8 The order of occurrence of the obligatory and optional KVN assignments shall be fixed as shown in table 3-3.

3.3.1.9 The Metadata Section shall describe the participants in a tracking session using the keyword 'PARTICIPANT_n'. There may be several participants associated with a tracking data session (the number of participants is always greater than or equal to one, and generally greater than or equal to two). The 'n' in the keyword is an indexer. The indexer shall not be the same for any two participants in a given Metadata Section.

3.3.1.10 The value associated with any given PARTICIPANT_n keyword may be a ground tracking station, a spacecraft, a quasar catalog name; or may include non-traditional objects, such as landers, rovers, balloons, etc. The list of eligible names that is used to specify participants should be documented in the ICD. Subsections 3.3.2 through 3.3.2.7 provide an explanation of the tracking modes and participant numbers. Participants may generally be listed in any order.

3.3.1.11 In this version of the TDM, the maximum number of participants per segment shall be five. If more than five participants are defined (i.e., PARTICIPANT_6 +), then special arrangements between exchange participants are necessary. These arrangements should be documented in an ICD. Note that although the restriction to five participants may appear to be a constraint it is probably not, because of other aspects of the TDM structure. Five participants easily allow the user to describe the great majority of tracking passes. In some cases there may be 'critical event' tracking sessions in which a single spacecraft is tracked by a large number of antennas, such that the total number of participants appears to be six or more. However, because of the nature of the 'PATH' keyword, several TDM Segments would be required to describe the full set of tracking data. For the critical event example scenario just given, one TDM Segment would be used to describe the two-way connection, and one additional segment would be required for each three-way connection; it would not be possible to provide a single 'PATH' statement that would convey the multiple signal paths.

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Table 3-3: TDM Metadata Section

Keyword	Description	Normative Values / Examples	N/E	Obligatory
META_START	The META_START keyword shall delineate the start of the TDM Metadata Section within the message. It must appear on a line by itself; i.e., it shall have no parameters, timetags or values.	N/A	----	Yes
COMMENT	See 4.5. Note that if comments are used in the metadata, they shall only appear at the beginning of the Metadata Section.	COMMENT file = tdm.dat	E	No
TIME_SYSTEM	The TIME_SYSTEM keyword shall specify the time system used for timetags in the associated Data Section. This should be UTC for ground-based data. The value associated with this keyword must be selected from the full set of allowed values enumerated in annex A.	UTC, TAI, GPS, SCLK	E	Yes
START_TIME	The START_TIME keyword shall specify the UTC start time of the total time span covered by the tracking data immediately following this Metadata Section. For format specification, see 4.3.9.	1996-12-18T14:28:15.1172 1996-277T07:22:54 2006-001T00:00:00Z	E	No
STOP_TIME	The STOP_TIME keyword shall specify the UTC stop time of the total time span covered by the tracking data immediately following this Metadata Section. For format specification, see 4.3.9.	1996-12-18T14:28:15.1172 1996-277T07:22:54 2006-001T00:00:00Z	E	No

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Keyword	Description	Normative Values / Examples	N/E	Obligatory
PARTICIPANT_n n = {1, 2, 3, 4, 5}	The PARTICIPANT_n keyword shall represent the participants in a tracking data session. It is indexed to allow unambiguous reference to other data in the TDM (max index is 5). At least two participants must be specified for most sessions; for some special TDMs such as tropospheric media only, only one participant need be listed. Participants may include ground stations, spacecraft, and/or quasars. Participants represent the classical transmitting parties, transponding parties, and receiving parties, while allowing for flexibility to consider tracking sessions that go beyond the familiar one-way spacecraft-to-ground, two-way ground-spacecraft-ground, etc. Participants may be listed in any order, and the PATH keywords specify the signal paths. For spacecraft identifiers, there is no CCSDS-based restriction on the value for this keyword, but names could be drawn from the SPACEWARN Bulletin (reference [5]), which includes Object name and international designator of the participant. The list of eligible names that is used to specify participants should be documented in the ICD.	DSS-63-S400K ROSETTA <Quasar catalog name> 1997-061A	E	Yes (at least one)
MODE	The MODE keyword shall reflect the tracking mode associated with the Data Section of the segment. The value 'SEQUENTIAL' applies only for range, Doppler, angles, and line-of-sight ionosphere calibrations; the name implies a sequential signal path between tracking participants. The value 'SINGLE_DIFF' applies for differenced data. In other cases, such as troposphere, weather, clocks, etc., use of the MODE keyword does not apply.	SEQUENTIAL SINGLE_DIFF	N	No