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Space data and information transfer systems — Orbit data messages

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National foreword

This British Standard is the UK implementation of ISO 26900:2012. It supersedes BS ISO 22664:2005, which is withdrawn.

This corrected version of ISO 26900:2012 also incorporates the corrections of Technical Corrigendum CCSDS 502.0-B-2 Cor. 1, May 2012. Corrections are identified in the enclosed CCSDS publication by a bar in the margin and the designation "Cor. 1". In addition, the list of equivalent references in Clause 2 of this International Standard has been updated.

The UK participation in its preparation was entrusted to Technical Committee ACE/68, Space systems and operations.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Space data and information transfer systems — Orbit data messages

*Systèmes de transfert des informations et données spatiales —
Messages pour données d'orbites*





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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 26900 was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 502.0-B-2, November 2009) 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 14, *Space systems and operations*, in collaboration with SC 13, *Space data and information transfer systems*.

ISO 26900 cancels and replaces ISO 22644:2006, which has been technically revised.

This corrected version of ISO 26900:2012 also incorporates the corrections of Technical Corrigendum CCSDS 502.0-B-2 Cor. 1, May 2012. Corrections are identified in the enclosed CCSDS publication by a bar in the margin and the designation "Cor. 1". In addition, the list of equivalent references in Clause 2 of this International Standard has been updated.

Space data and information transfer systems — Orbit data messages

1 Scope

This International Standard specifies three standard message formats for use in transferring spacecraft orbit information between space agencies and commercial or governmental spacecraft operators: the Orbit Parameter Message (OPM), the Orbit Mean-Elements Message (OMM), and the Orbit Ephemeris Message (OEM). Such exchanges are used for

- a) pre-flight planning for tracking or navigation support,
- b) scheduling tracking support,
- c) carrying out tracking operations (sometimes called metric predicts),
- d) performing orbit comparisons,
- e) carrying out navigation operations such as orbit propagation and orbit reconstruction,
- f) assessing mutual physical and electromagnetic interference among satellites orbiting the same celestial body (currently primarily Earth, Moon, and Mars),
- g) performing orbit conjunction (collision avoidance) studies, and
- h) developing and executing collaborative manoeuvres to mitigate interference or enhance mutual operations.

This International Standard includes sets of requirements and criteria that the message formats have been designed to meet.

NOTE For exchanges where these requirements do not capture the needs of the participating agencies and satellite operators, another mechanism can be selected.

The scope and field of application are furthermore detailed in subclauses 1.1 and 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 502.0-B-2, November 2009, *Orbit data messages*.

For the purposes of international standardization, the modifications outlined below shall apply to the specific clauses and paragraphs of publication CCSDS 502.0-B-2.

Pages i to v

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

Page 1-3

Add the following information to the reference indicated:

[1] Document CCSDS 301.0-B-4, November 2010, is equivalent to ISO 11104:2011.

[4] Document CCSDS 505.0-B-1, December 2010, is equivalent to ISO 17107:2011

Page G-1

Add the following information to the reference indicated:

[G5] Document CCSDS 504.0-B-1, May 2008, is equivalent to ISO 13541:2010.

3 Revision of publication CCSDS 502.0-B-2

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 502.0-B-2. To this end, NASA will act as a liaison body between CCSDS and ISO.



Recommendation for Space Data System Standards

ORBIT DATA MESSAGES

RECOMMENDED STANDARD

CCSDS 502.0-B-2

Note:
This current
issue includes
all updates through
Technical Corrigendum 1,
dated May 2012.

BLUE BOOK
November 2009

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CCSDS RECOMMENDED STANDARD FOR ORBIT DATA MESSAGES

AUTHORITY

Issue:	Recommended Standard, Issue 2
Date:	November 2009
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 documents 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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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.

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 - The **standard** itself.
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 - The anticipated duration of operational service.
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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 ORBIT DATA MESSAGES

FOREWORD

This document is a Recommended Standard for Orbit Data Messages (ODMs) and has been prepared by the Consultative Committee for Space Data Systems (CCSDS). The set of orbit data messages described in this Recommended Standard is the baseline concept for trajectory representation in 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 interchange of orbit data. 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 of this document may occur. This Recommended Standard is therefore subject to CCSDS document management and change control procedures, which are 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 ORBIT DATA MESSAGES

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

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- European Space Agency (ESA)/Europe.
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- National Oceanic and Atmospheric Administration (NOAA)/USA.
- National Space Organization (NSPO)/Chinese Taipei.
- Naval Center for Space Technology (NCST)/USA.
- Scientific and Technological Research Council of Turkey (TUBITAK)/Turkey.
- Space and Upper Atmosphere Research Commission (SUPARCO)/Pakistan.
- Swedish Space Corporation (SSC)/Sweden.
- United States Geological Survey (USGS)/USA.

CCSDS RECOMMENDED STANDARD FOR ORBIT DATA MESSAGES

DOCUMENT CONTROL

Document	Title	Date	Status
CCSDS 502.0-B-1	Orbit Data Messages, Issue 1	September 2004	Original issue, superseded
CCSDS 502.0-B-2	Orbit Data Messages, Recommended Standard, Issue 2	November 2009	Current issue: – changes from the original issue are documented in annex E
EC 1	Editorial Change 1	April 2012	Corrects erroneous cross references and table of contents entries; corrects typographical anomaly in annex B; updates informative references [G1] and [G2] to current issues in annex G.
CCSDS 502.0-B-2 Cor. 1	Technical Corrigendum 1	May 2012	Corrects/clarifies text; updates references [1] and [4] to current issues in 1.7.

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CCSDS RECOMMENDED STANDARD FOR ORBIT DATA MESSAGES

1 INTRODUCTION

1.1 PURPOSE AND SCOPE

This Orbit Data Message (ODM) Recommended Standard specifies three standard message formats for use in transferring spacecraft orbit information between space agencies and commercial or governmental spacecraft operators: the Orbit Parameter Message (OPM), the Orbit Mean-Elements Message (OMM), and the Orbit Ephemeris Message (OEM). Such exchanges are used for:

- a) pre-flight planning for tracking or navigation support;
- b) scheduling tracking support;
- c) carrying out tracking operations (sometimes called metric predicts);
- d) performing orbit comparisons;
- e) carrying out navigation operations such as orbit propagation and orbit reconstruction;
- f) assessing mutual physical and electromagnetic interference among satellites orbiting the same celestial body (currently primarily Earth, Moon, and Mars);
- g) performing orbit conjunction (collision avoidance) studies; and
- h) developing and executing collaborative maneuvers to mitigate interference or enhance mutual operations.

This Recommended Standard includes sets of requirements and criteria that the message formats have been designed to meet. For exchanges where these requirements do not capture the needs of the participating agencies and satellite operators, another mechanism may be selected.

1.2 APPLICABILITY

The rationale behind the design of each orbit data message is described in annex C and may help the application engineer to select a suitable message. Definition of the orbit accuracy underlying a particular orbit message is outside of the scope of this Recommended Standard and should be specified via Interface Control Document (ICD) between data exchange participants (or specified via COMMENT sections in the message itself). Applicability information specific to each orbit data message format appears in sections 3, 4, and 5, as well as in C3.

This Recommended Standard is applicable only to the message format and content, but not to its transmission. The transmission of the message between agencies and operators is outside the scope of this document and should be specified in the ICD.

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Description of the message formats based on the use of Extensible Markup Language (XML) is detailed in an integrated XML schema document for all Navigation Data Message Recommended Standards. (See reference [4].)

1.3 RATIONALE

This update to version 1 of the Orbit Data Messages adds a third message type based on collaboration of the CCSDS Navigation Working Group and the ISO Technical Committee 20, Subcommittee 14, Working Group 3 (ISO TC20/SC14/WG3). Additionally, added to the messages in the previous version are data structures that provide information regarding the uncertainty of the orbital states represented in the messages. Such information will increase the number of applications for which the messages are useful. A full list of the changes in this document is located in annex E.

1.4 DOCUMENT STRUCTURE

Section 2 provides a brief overview of the CCSDS-recommended Orbit Data Message types, the Orbit Parameter Message (OPM), Orbit Mean-Elements Message (OMM), and Orbit Ephemeris Message (OEM).

Section 3 provides details about the structure and content of the OPM.

Section 4 provides details about the structure and content of the OMM.

Section 5 provides details about the structure and content of the OEM.

Section 6 discusses the syntax considerations of the set of Orbit Data Messages (OPM, OMM, OEM).

Section 7 discusses security requirements for the Orbit Data Messages.

Annex A lists acceptable values for selected ODM keywords.

Annex B is a list of abbreviations and acronyms applicable to the ODM.

Annex C lists a set of requirements that were taken into consideration in the design of the OPM, OMM, and OEM, along with tables and discussion regarding the applicability of the three message types to various navigation tasks/functions.

Annex D lists a number of items that should be covered in ICDs prior to exchanging ODMs on a regular basis. There are several statements throughout the document that refer to the desirability or necessity of such a document; this annex lists all the suggested ICD items in a single place in the document. Also provided is a set of generic comment statements that may be added to one of the Orbit Data Messages to convey supplementary information for scenarios in which there is no ICD in place.

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Annex E provides a summary of the changes introduced in this version 2 of the ODM and documents the differences between ODM version 1 and ODM version 2.

Annex F provides instructions for how to produce a version 2 OPM/OEM that is backwards compatible to version 1 implementations.

Annex G provides a listing of informative references.

1.5 DEFINITIONS

For the purposes of this document, the following definitions apply:

- a) the word ‘agencies’ may also be construed as meaning ‘satellite operators’ or ‘satellite service providers’;
- b) 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 tracking station, a tracking instrument, or an agency/operator;
- c) the notation ‘n/a’ signifies ‘not applicable’;
- d) depending on context, the term ‘ODM’ may be used to refer to this document, or may be used to refer collectively to the OPM, OMM and OEM messages.

1.6 NOMENCLATURE

The following conventions apply throughout this Recommended Standard:

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

1.7 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] *Time Code Formats*. Recommendation for Space Data System Standards, CCSDS 301.0-B-4. Blue Book. Issue 4. Washington, D.C.: CCSDS, November 2010.

Cor. 1

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- [2] *Spacewarn Bulletin*. Greenbelt, MD, USA: World Data Center for Satellite Information: WDC-SI. <<http://nssdc.gsfc.nasa.gov/spacewarn>>
- [3] *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.
- [4] *XML Specification for Navigation Data Messages*. Recommendation for Space Data System Standards, CCSDS 505.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, December 2010.
- [5] “JPL Solar System Dynamics.” Solar System Dynamics Group. <<http://ssd.jpl.nasa.gov/>>
- [6] Paul V. Biron and Ashok Malhotra, eds. *XML Schema Part 2: Datatypes*. 2nd Edition. W3C Recommendation. N.p.: W3C, October 2004. <<http://www.w3.org/TR/2001/REC-xmlschema-2-20010502/>>
- [7] *IEEE Standard for Binary Floating-Point Arithmetic*. IEEE Std 754-1985. New York: IEEE, 1985.

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CCSDS RECOMMENDED STANDARD FOR ORBIT DATA MESSAGES

2 OVERVIEW

2.1 ORBIT DATA MESSAGE TYPES

Three CCSDS-recommended Orbit Data Messages (ODMs) are described in this Recommended Standard: the Orbit Parameter Message (OPM), the Orbit Mean-Elements Message (OMM), and the Orbit Ephemeris Message (OEM).

The recommended orbit data messages are ASCII text format (reference [3]). This ODM document describes 'keyword = value notation' formatted messages, while reference [4] describes XML formatted messages (the ICD should specify which of these formats will be exchanged).

NOTE – As currently specified, an OPM, OMM, or OEM file is to represent orbit data for a single spacecraft. It is possible that the architecture may support multiple spacecraft per file; this could be considered in the future.

2.2 ORBIT PARAMETER MESSAGE (OPM)

An OPM specifies the position and velocity of a single object at a specified epoch. Optionally, osculating Keplerian elements may be provided. This message is suited to exchanges that (1) involve automated interaction and/or human interaction, and (2) do not require high-fidelity dynamic modeling.

The OPM requires the use of a propagation technique to determine the position and velocity at times different from the specified epoch, leading to a higher level of effort for software implementation than for the OEM. A 6x6 position/velocity covariance matrix that may be used in the propagation process is optional.

The OPM allows for modeling of any number of maneuvers (as both finite and instantaneous events) and simple modeling of solar radiation pressure and atmospheric drag.

The OPM also contains an optional covariance matrix which reflects the uncertainty of the orbit state.

Though primarily intended for use by computers, the attributes of the OPM also make it suitable for applications such as exchanges by email, FAX or voice, or applications where the message is to be frequently interpreted by humans.

2.3 ORBIT MEAN-ELEMENTS MESSAGE (OMM)

An OMM specifies the orbital characteristics of a single object at a specified epoch, expressed in mean Keplerian elements. This message is suited to exchanges that (1) involve automated interaction and/or human interaction, and (2) do not require high-fidelity dynamic modeling. Such exchanges may be inter-agency exchanges, or ad hoc exchanges among satellite operators when interface control documents have not been negotiated. Ad hoc

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interactions usually involve more than one satellite, each satellite controlled and operated by a different operating authority.

The OMM includes keywords and values that can be used to generate canonical NORAD Two Line Element Sets (TLEs) to accommodate the needs of heritage users (see reference [G4]).

The OMM also contains an optional covariance matrix which reflects the uncertainty of the mean Keplerian elements. This information may be used to determine contact parameters that encompass uncertainties in predicted future states of orbiting objects of interest.

This message is suited for directing antennas and planning contacts with satellites. It is not recommended for assessing mutual physical or electromagnetic interference among Earth-orbiting spacecraft, developing collaborative maneuvers, or propagating precisely the orbits of active satellites, inactive man made objects, and near-Earth debris fragments. It is not suitable for numerical integration of the governing equations.

Though primarily intended for use by computers, the attributes of the OMM also make it suitable for applications such as exchanges by email, FAX or voice, or applications where the message is to be frequently interpreted by humans.

2.4 ORBIT EPHEMERIS MESSAGE (OEM)

An OEM specifies the position and velocity of a single object at multiple epochs contained within a specified time range. The OEM is suited to exchanges that (1) involve automated interaction (e.g., computer-to-computer communication where frequent, fast automated time interpretation and processing is required), and (2) require higher fidelity or higher precision dynamic modeling than is possible with the OPM.

The OEM allows for dynamic modeling of any number of gravitational and non-gravitational accelerations. The OEM requires the use of an interpolation technique to interpret the position and velocity at times different from the tabular epochs.

The OEM also contains an optional covariance matrix which reflects the uncertainty of the orbit solution used to generate states in the ephemeris.

2.5 EXCHANGE OF MULTIPLE MESSAGES

For a given object, multiple OPM, OMM, or OEM messages may be provided in a message exchange session to achieve ephemeris fidelity requirements. If ephemeris information for multiple objects is to be exchanged, then multiple OPM, OMM, or OEM files must be used.

2.6 DEFINITIONS

Definitions of time systems, reference frames, planetary models, maneuvers and other fundamental topics related to the interpretation and processing of state vectors and spacecraft ephemerides are provided in reference [G1].

3 ORBIT PARAMETER MESSAGE (OPM)

3.1 GENERAL

3.1.1 Orbit information may be exchanged between two participants by sending a state vector (see reference [G1]) for a specified epoch using an Orbit Parameter Message (OPM). The message recipient must have an orbit propagator available that is able to propagate the OPM state vector to compute the orbit at other desired epochs. For this propagation, additional ancillary information (spacecraft properties such as mass, area, and maneuver planning data, if applicable) may be included with the message.

3.1.2 Osculating Keplerian elements and Gravitational Coefficient may be included in the OPM in addition to the Cartesian state to aid the message recipient in performing consistency checks. If any Keplerian element is included, the entire set of elements must be provided.

3.1.3 If participants wish to exchange mean element information, then the Orbit Mean-Elements Message (OMM) should be the selected message type. (See section 4.)

3.1.4 The use of the OPM is best applicable under the following conditions:

- a) an orbit propagator consistent with the models used to develop the orbit data should be available at the receiver's site;
- b) the receiver's modeling of gravitational forces, solar radiation pressure, atmospheric drag, and thrust phases (see reference [G1]) should fulfill accuracy requirements established between the exchange partners.

3.1.5 The OPM shall be a plain text file consisting of orbit data for a single object. It shall be easily readable by both humans and computers.

3.1.6 The OPM file-naming scheme should be agreed to on a case-by-case basis between the exchange partners, and should be documented in an ICD. The method of exchanging OPMs should be decided on a case-by-case basis by the exchange partners and documented in an ICD.

NOTE – Detailed syntax rules for the OPM are specified in section 6.

3.2 OPM CONTENT/STRUCTURE

3.2.1 GENERAL

The OPM shall be represented as a combination of the following:

- a) a header;
- b) metadata (data about data);
- c) data; and
- d) optional comments (explanatory information).

3.2.2 OPM HEADER

3.2.2.1 Table 3-1 specifies for each header item:

- a) the keyword to be used;
- b) a short description of the item;
- c) examples of allowed values; and
- d) whether the item is obligatory or optional.

3.2.2.2 Only those keywords shown in table 3-1 shall be used in an OPM header.

Table 3-1: OPM Header

Keyword	Description	Examples of Values	Obligatory
CCSDS_OPM_VERS	Format version in the form of 'x.y', where 'y' is incremented for corrections and minor changes, and 'x' is incremented for major changes.	2.0	Yes
COMMENT	Comments (allowed in the OPM Header only immediately after the OPM version number). (See 6.7 for formatting rules.)	COMMENT This is a comment	No
CREATION_DATE	File creation date/time in UTC. (For format specification, see 6.5.9.)	2001-11-06T11:17:33 2002-204T15:56:23Z	Yes
ORIGINATOR	Creating agency or operator (value should be specified in an ICD). The country of origin should also be provided where the originator is not a national space agency.	CNES, ESOC, GSFC, GSOC, JPL, JAXA, INTELSAT/USA, USAF, INMARSAT/UK	Yes

3.2.3 OPM METADATA

3.2.3.1 Table 3-2 specifies for each metadata item:

- a) the keyword to be used;
- b) a short description of the item;
- c) examples of allowed values; and
- d) whether the item is obligatory or optional.

3.2.3.2 Only those keywords shown in table 3-2 shall be used in OPM metadata.

NOTE – For some keywords (OBJECT_NAME, OBJECT_ID, CENTER_NAME) there are no definitive lists of authorized values maintained by a control authority; the references listed in 1.7 are the best known sources for authorized values to date. For the TIME_SYSTEM and REF_FRAME keywords, the approved values are listed in annex A.