

Space data and information transfer systems — TM (telemetry) synchronization and channel coding

ICS 49.140

National foreword

This British Standard reproduces verbatim ISO 22641:2005 and implements it as the UK national standard.

The UK participation in its preparation was entrusted by Technical Committee ACE/68, Space systems and operations, to Subcommittee ACE/68/-/7, Space systems and operations — Space data and information transfer systems, which has the responsibility to:

- aid enquirers to understand the text;
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The British Standards which implement international publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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Summary of pages

This document comprises a front cover, an inside front cover, the ISO title page, pages ii and iii, a blank page, pages 1 to 80, an inside back cover and a back cover.

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INTERNATIONAL STANDARD

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Space data and information transfer systems — TM (telemetry) synchronization and channel coding

*Systèmes de transfert des données et informations spatiales —
Synchronisation TM (télémétrie) et codage de canal*



Reference number
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Foreword

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ISO 22641 was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 131.0-B-1, September 2003) 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*.

Space data and information transfer systems — TM (telemetry) synchronization and channel coding

1 Scope

This International Standard specifies synchronization and channel coding schemes used in conjunction with the telemetry (TM) space data link protocol as defined by ISO 22645 or the advanced orbiting systems (AOS) space data link protocol defined by ISO 22666. These schemes are to be used over space-to-ground or space-to-space communications links by space missions.

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 131.0-B-1, September 2003, TM *synchronization and channel coding*.

For the purposes of international standardization, the modifications outlined below shall apply to the specific clauses and paragraphs of publication CCSDS 131.0-B-1.

Pages i to v

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

Page 1-5

Add the following information to the references indicated:

[1] Document CCSDS 132.0-B-1, September 2003, is equivalent to ISO 22645:2005.

[2] Document CCSDS 732.0-B-1, September 2003, is equivalent to ISO 22666:2005.

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Add the following information to the references indicated:

[B2] Document CCSDS 101.0-B-6, October 2002, is equivalent to ISO 11754:—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 131.0-B-1. To this end, NASA will act as a liaison body between CCSDS and ISO.

1) To be published. (Revision of ISO 11754:2003)

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Consultative Committee for Space Data Systems

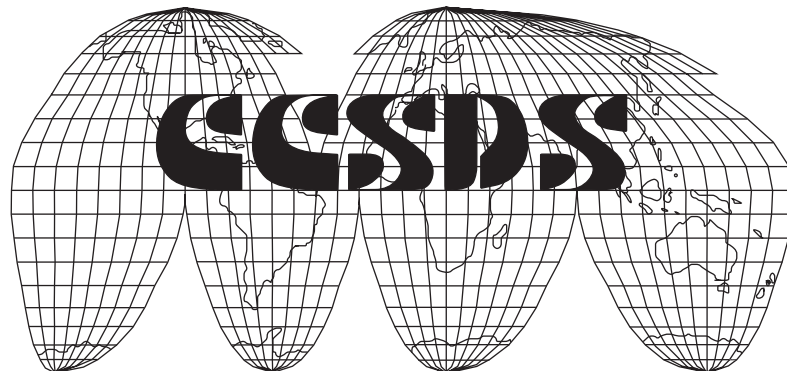
RECOMMENDATION FOR SPACE
DATA SYSTEM STANDARDS

TM SYNCHRONIZATION AND CHANNEL CODING

CCSDS 131.0-B-1

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CCSDS RECOMMENDATION FOR TM SYNCHRONIZATION AND CHANNEL CODING

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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* (reference [B1]), and the record of Agency participation in the authorization of this document can be obtained from the CCSDS Secretariat at the address below.

This Recommendation 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 member space Agencies. 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 **Recommendations** and are not considered binding on any Agency.

This **Recommendation** is issued by, and represents the consensus of, the CCSDS Plenary body. Agency endorsement of this **Recommendation** is entirely voluntary. Endorsement, however, indicates the following understandings:

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 - The **standard** itself.
 - The anticipated date of initial operational capability.
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In those instances when a new version of a **Recommendation** is issued, existing CCSDS-related Agency standards and implementations are not negated or deemed to be non-CCSDS compatible. It is the responsibility of each Agency to determine when such standards or implementations are to be modified. Each Agency is, however, strongly encouraged to direct planning for its new standards and implementations towards the later version of the Recommendation.

CCSDS RECOMMENDATION FOR TM SYNCHRONIZATION AND CHANNEL CODING

FOREWORD

This document is a technical Recommendation for use in developing synchronization and channel coding systems and has been prepared by the Consultative Committee for Space Data Systems (CCSDS). The synchronization and channel coding concept described herein is intended for missions that are cross-supported between Agencies of the CCSDS.

This Recommendation establishes a common framework and provides a common basis for the synchronization and channel coding schemes to be used by space missions with the TM or AOS Space Data Link Protocol (references [1] or [2]) over space-to-ground and space-to-space communications links. This Recommendation was developed by consolidating the specifications regarding synchronization and channel coding in older CCSDS Recommendations [B2] and [B3].

This Recommendation does not change the major technical contents defined in [B2] and [B3], but the presentation of the specification has been changed so that:

- a) these schemes can be used to transfer any data over any space link in either direction;
- b) all CCSDS space link protocols are specified in a unified manner;
- c) the layered model matches the Open Systems Interconnection (OSI) Basic Reference Model (reference [3]).

Together with the change in presentation, a few technical specifications in [B2] and [B3] have been changed in order to define all Space Data Link Protocols in a unified way. Also, some technical terms in references [B2] and [B3] have been changed in order to unify the terminology used in all the CCSDS Recommendations that define space link protocols and to define these schemes as general communications schemes. These changes are listed in annex E of this Recommendation.

Through the process of normal evolution, it is expected that expansion, deletion or modification to this document may occur. This Recommendation 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:

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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 RECOMMENDATION FOR TM SYNCHRONIZATION AND CHANNEL CODING

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CCSDS RECOMMENDATION FOR TM SYNCHRONIZATION AND CHANNEL CODING

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CCSDS RECOMMENDATION FOR TM SYNCHRONIZATION AND CHANNEL CODING

1 INTRODUCTION

1.1 PURPOSE

The purpose of this Recommendation is to specify synchronization and channel coding schemes used with the TM Space Data Link Protocol (reference [1]) or the AOS Space Data Link Protocol (reference [2]). These schemes are to be used over space-to-ground or space-to-space communications links by space missions.

1.2 SCOPE

This Recommendation defines synchronization and channel coding schemes in terms of:

- a) the services provided to the users of this specification;
- b) data formats; and
- c) the procedures performed to generate and process the data formats.

It does not specify:

- a) individual implementations or products;
- b) the methods or technologies required to perform the procedures; or
- c) the management activities required to configure and control the system.

1.3 APPLICABILITY

This Recommendation applies to the creation of Agency standards and to the future data communications over space links between CCSDS Agencies in cross-support situations. This Recommendation includes comprehensive specification of the data formats and procedures for inter-Agency cross support. It is neither a specification of, nor a design for, real systems that may be implemented for existing or future missions.

The Recommendation specified in this document is to be invoked through the normal standards programs of each CCSDS Agency, and is applicable to those missions for which cross support based on capabilities described in this Recommendation is anticipated. Where mandatory capabilities are clearly indicated in sections of this Recommendation, they must be implemented when this document is used as a basis for cross support. Where options are allowed or implied, implementation of these options is subject to specific bilateral cross support agreements between the Agencies involved.

1.4 RATIONALE

The CCSDS believes it is important to document the rationale underlying the recommendations chosen, so that future evaluations of proposed changes or improvements will not lose sight of previous decisions.

1.5 DOCUMENT STRUCTURE

This document is divided into nine numbered sections and six annexes:

- a) section 1 presents the purpose, scope, applicability and rationale of this Recommendation and lists the conventions, definitions, and references used throughout the document;
- b) section 2 provides an overview of synchronization and channel coding;
- c) section 3 specifies the convolutional coding;
- d) section 4 specifies the Reed-Solomon coding;
- e) section 5 specifies the turbo coding;
- f) section 6 specifies the frame synchronization scheme;
- g) section 7 specifies the Pseudo-Randomizer;
- h) section 8 specifies the allowed lengths of Transfer Frames;
- i) section 9 lists the managed parameters associated with synchronization and channel coding;
- j) annex A lists acronyms and terms used within this document;
- k) annex B provides a list of informative references;
- l) annex C defines the service provided to the users;
- m) annex D provides information on transformation between the Berlekamp (dual basis) and Conventional representations;
- n) annex E provides information on Reed-Solomon coefficients;
- o) annex F lists the changes from relevant previously published CCSDS Recommendations [B2] and [B3].

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1.6 CONVENTIONS AND DEFINITIONS

1.6.1 DEFINITIONS

1.6.1.1 Definitions from the Open System Interconnection (OSI) Basic Reference Model

This Recommendation makes use of a number of terms defined in reference [3]. The use of those terms in this Recommendation shall be understood in a generic sense; i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are:

- a) Data Link Layer;
- b) Physical Layer;
- c) service;
- d) service data unit.

1.6.1.2 Definitions from OSI Service Definition Conventions

This Recommendation makes use of a number of terms defined in reference [4]. The use of those terms in this Recommendation shall be understood in a generic sense; i.e., in the sense that those terms are generally applicable to any of a variety of technologies that provide for the exchange of information between real systems. Those terms are:

- a) indication;
- b) primitive;
- c) request;
- d) service provider;
- e) service user.

1.6.1.3 Terms Defined in This Recommendation

For the purposes of this Recommendation, the following definitions apply. Many other terms that pertain to specific items are defined in the appropriate sections.

asynchronous: not *synchronous*.

Mission Phase: a period of a mission during which specified communications characteristics are fixed. The transition between two consecutive mission phases may cause an interruption of the communications services.

Physical Channel: a stream of bits transferred over a space link in a single direction.

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space link: a communications link between a spacecraft and its associated ground system or between two spacecraft. A space link consists of one or more Physical Channels in one or both directions.

synchronous: of or pertaining to a sequence of events occurring in a fixed time relationship (within specified tolerance) to another sequence of events.

1.6.2 NOMENCLATURE

The following conventions apply throughout this Recommendation:

- 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.

1.6.3 CONVENTIONS

In this document, the following convention is used to identify each bit in an N -bit field. The first bit in the field to be transmitted (i.e., the most left justified when drawing a figure) is defined to be 'Bit 0', the following bit is defined to be 'Bit 1', and so on up to 'Bit $N-1$ '. When the field is used to express a binary value (such as a counter), the Most Significant Bit (MSB) shall be the first transmitted bit of the field, i.e., 'Bit 0' (see figure 1-1).



Figure 1-1: Bit Numbering Convention

In accordance with standard data-communications practice, data fields are often grouped into 8-bit 'words' which conform to the above convention. Throughout this Recommendation, such an 8-bit word is called an 'octet'.

The numbering for octets within a data structure starts with '0'.

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1.7 REFERENCES

The following documents contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Recommendation 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 Recommendations.

- [1] *TM Space Data Link Protocol*. Recommendation for Space Data Systems Standards, CCSDS 132.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.
- [2] *AOS Space Data Link Protocol*. Recommendation for Space Data Systems Standards, CCSDS 732.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, September 2003.
- [3] *Information Technology—Open Systems Interconnection—Basic Reference Model: The Basic Model*. International Standard, ISO/IEC 7498-1. 2nd ed.. Geneva: ISO, 1994.
- [4] *Information Technology—Open Systems Interconnection—Basic Reference Model—Conventions for the definition of OSI services*. International Standard, ISO/IEC 10731:1994. Geneva: ISO, 1994.
- [5] *Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft*. Recommendation for Space Data Systems Standards, CCSDS 401.0-B. Blue Book. Washington, D.C.: CCSDS, March 2003.

NOTE – Informative references are listed in annex B.

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2 OVERVIEW

2.1 ARCHITECTURE

Figure 2-1 illustrates the relationship of this Recommendation to the Open Systems Interconnection reference model (reference [3]). Two sublayers of the Data Link Layer are defined for CCSDS space link protocols. The TM and AOS Space Data Link Protocols specified in references [1] and [2], respectively, correspond to the Data Link Protocol Sublayer, and provide functions for transferring data using the protocol data unit called the Transfer Frame. The Synchronization and Channel Coding Sublayer provides additional functions necessary for transferring Transfer Frames over a space link. These functions are error-control coding/decoding, Transfer Frame delimiting/synchronizing, and bit transition generation/removal.

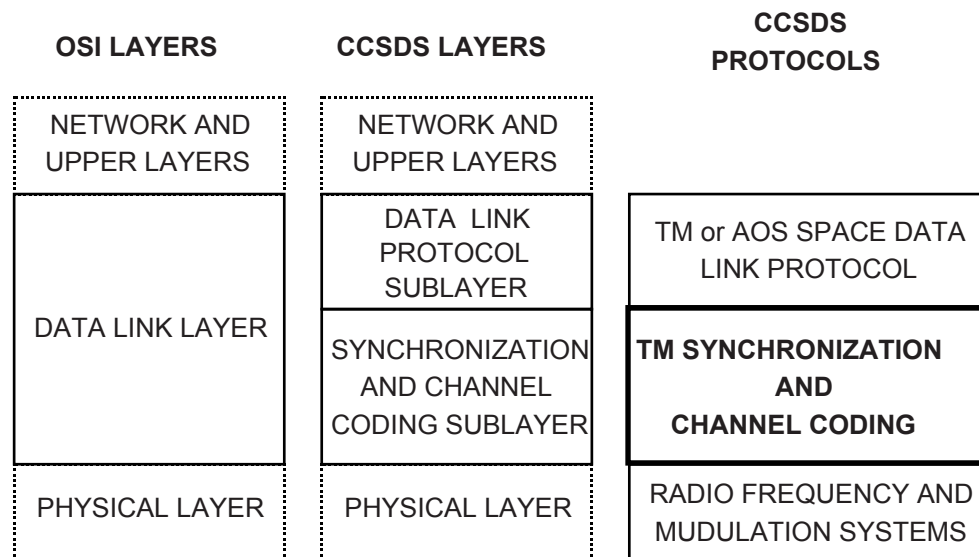


Figure 2-1: Relationship with OSI Layers

2.2 SUMMARY OF FUNCTIONS

2.2.1 GENERAL

The Synchronization and Channel Coding Sublayer provides the following three functions for transferring Transfer Frames over a space link:

- error-control coding, including frame validation (optional);
- synchronization; and
- pseudo-randomizing (optional).

2.2.2 ERROR-CONTROL CODING

This Recommendation specifies the following three types of error-control codes:

- a) convolutional codes (section 3);
- b) Reed-Solomon codes (section 4);
- c) turbo codes (section 5).

One of the convolutional codes described in section 3 alone may be satisfactory depending on performance requirements.

For Physical Channels which are bandwidth-constrained and cannot tolerate the increase in bandwidth required by the basic convolutional code specified in 3.1, the punctured convolutional code specified in 3.2 has the advantage of smaller bandwidth expansion.

For Physical Channels which are bandwidth-constrained and cannot tolerate the increase in bandwidth required by the convolutional codes, the Reed-Solomon codes specified in section 4 have the advantage of smaller bandwidth expansion and have the capability to indicate the presence of uncorrectable errors. Where a greater coding gain is needed than can be provided by a convolutional code or Reed-Solomon code alone, a concatenation of a convolutional code as the inner code with a Reed-Solomon code as the outer code may be used for improved performance.

The turbo codes specified in section 7 may be used to obtain even greater coding gain where the environment permits.

NOTE – In this Recommendation, the characteristics of the codes are specified only to the extent necessary to ensure interoperability and cross-support. The specification does not attempt to quantify the relative coding gain or the merits of each approach discussed, nor does it specify the design requirements for encoders or decoders.

Some codes are also used to check whether or not each decoded Transfer Frame can be used as a valid data unit by the upper layers at the receiving end. This function is called Frame Validation. The Reed-Solomon decoder can determine, with a very high probability, whether or not it can correctly decode a Transfer Frame. Therefore, the Reed-Solomon code is also used for Frame Validation. When the Reed-Solomon code is not used, the Frame Error Control Field defined in references [1] or [2] shall be used for Frame Validation.

NOTE – Frame Validation explained above presupposes correct frame synchronization. That is, a Transfer Frame declared valid by the Reed-Solomon decoder is valid only if the Transfer Frame is correctly synchronized. If a Transfer Frame is not correctly synchronized, then the Reed-Solomon decoder may perform meaningless error correction against the Transfer Frame and declare it valid.

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2.2.3 SYNCHRONIZATION

This Recommendation specifies a method for synchronizing Transfer Frames using an Attached Sync Marker (ASM) (see section 6).

The ASM may also be used for resolution of data ambiguity (sense of '1' and '0') if data ambiguity is not resolved by the modulation method used in the Physical Layer.

2.2.4 PSEUDO-RANDOMIZING

This Recommendation specifies an optional pseudo-randomizer to improve symbol transition density as an aid to bit synchronization (see section 7).

2.3 INTERNAL ORGANIZATION OF SUBLAYER

2.3.1 SENDING END

Figure 2-2 shows the internal organization of the Synchronization and Channel Coding Sublayer of the sending end. This figure identifies functions performed by the sublayer and shows logical relationships among these functions. The figure is not intended to imply any hardware or software configuration in a real system. Depending on the options actually used for a mission, not all of the functions may be present in the sublayer.

At the sending end, the Synchronization and Channel Coding Sublayer accepts Transfer Frames of fixed length from the Data Link Protocol Sublayer (see figure 2-1), performs functions selected for the mission, and delivers a continuous and contiguous stream of channel symbols to the Physical Layer.