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Space data and information transfer systems — Delta- differential one-way ranging (Delta-DOR) operations

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Space data and information transfer systems — Delta-differential one-way ranging (Delta-DOR) operations

*Systèmes de transfert des données et informations spatiales —
Exploitation de mesures différentielles de distance par triangulation
(Delta DOR)*



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Foreword

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ISO 17809 was prepared by the Consultative Committee for Space Data Systems (CCSDS) (as CCSDS 506.0-M-1, April 2011) 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 — Delta-differential one-way ranging (Delta-DOR) operations

1 Scope

Delta Differential One-Way Ranging (Delta-DOR) operations are applicable to space agencies that operate deep space missions that require accurate determination of the spacecraft position in the plane of the sky. For operations where these requirements do not capture the needs of the participating agencies, Delta-DOR operations may not be appropriate.

This International Standard addresses rationale, requirements and criteria that Delta-DOR operations processes should be designed to meet.

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 506.0-M-1, April 2011, Delta-Differential One Way Ranging (Delta-DOR) Operations

For the purposes of international standardization, the modifications outlined below shall apply to the specific clauses and paragraphs of publication CCSDS 506.0-M-1.

Pages i to vi

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

Page 1-3

Add the following information to the reference indicated:

[2] Document CCSDS 502.0-B-2, November 2009, is equivalent to ISO 26900:2012.

[3] Document CCSDS 503.0-B-1, November 2007, is equivalent to ISO 13536:2010.

Page D-1

Add the following information to the reference indicated:

[D6] Document CCSDS 505.0-B-1, December 2010, is equivalent to ISO 17107:2011.

Page D-2

Add the following information to the reference indicated:

[D11] Document CCSDS 301.0-B-4, November 2010, is equivalent to ISO 11104:2011.

[D12] Document CCSDS 910.11-B-1, August 2009, is equivalent to ISO 18439:2013.

3 Revision of publication CCSDS 506.0-M-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 506.0-M-1. To this end, NASA will act as a liaison body between CCSDS and ISO.

Recommendation for Space Data System Practices

DELTA-DIFFERENTIAL ONE WAY RANGING (DELTA-DOR) OPERATIONS

RECOMMENDED PRACTICE

CCSDS 506.0-M-1

MAGENTA BOOK

April 2011

AUTHORITY

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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 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.

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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 **Recommendations** and are not in themselves considered binding on any Agency.

CCSDS Recommendations take two forms: **Recommended Standards** that are prescriptive and are the formal vehicles by which CCSDS Agencies create the standards that specify how elements of their space mission support infrastructure shall operate and interoperate with others; and **Recommended Practices** that are more descriptive in nature and are intended to provide general guidance about how to approach a particular problem associated with space mission support. This **Recommended Practice** is issued by, and represents the consensus of, the CCSDS members. Endorsement of this **Recommended Practice** is entirely voluntary and does not imply a commitment by any Agency or organization to implement its recommendations in a prescriptive sense.

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

FOREWORD

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

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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.

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

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- Chinese Academy of Sciences (CAS)/China.
- Chinese Academy of Space Technology (CAST)/China.
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- Korea Aerospace Research Institute (KARI)/Korea.
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- National Oceanic and Atmospheric Administration (NOAA)/USA.
- National Space Agency of the Republic of Kazakhstan (NSARK)/Kazakhstan.
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- 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.

DOCUMENT CONTROL

Document	Title	Date	Status
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1 INTRODUCTION

1.1 PURPOSE

This Recommended Practice specifies a set of standard practices and message formats for use in the navigation technique known as Delta Differential One-Way Ranging (Delta-DOR). It has been developed via consensus of the Delta-DOR Working Group of the CCSDS Systems Engineering Area (SEA).

Delta-DOR is a Very Long Baseline Interferometry (VLBI) technique that can be used in conjunction with Doppler and ranging data to improve spacecraft navigation by more efficiently determining spacecraft angular position in the plane of sky. The establishment of interoperability for acquiring and processing Delta-DOR data at ground stations of different agencies, the standardization of service requests for Delta-DOR, the standardization of an exchange format for raw data, and standardization of interfaces for exchange of supporting products are key enablers for interagency execution of Delta-DOR operations.

The Recommended Practice addresses aspects of the technique that require standardization in order to enable Delta-DOR interoperability between space agencies, e.g., configuration requirements for interagency Delta-DOR measurement; interagency exchange of measurement data; parameters that are necessary in order to correlate and process the data at one of the agencies; interagency transfer of the generated observables; and the end-to-end flow of control. It is believed that such standards will reduce development and operations costs while improving navigation capabilities by increasing the number of intercontinental ground station baselines.

There are essentially three parts to providing Delta-DOR services, the first being the definition of the RF domain signals and reception, the second being the definition of the input and output data products, and the third being the definition of the method for requesting service and transferring data products. The first of these is allocated to the CCSDS Space Link Service (SLS) Area (reference [1]); the second is allocated to the Mission Operations and Information Management Services (MOIMS) Area (reference [3]); the third will be developed as SLE Service Request extensions which will be allocated to the Service Management Working Group within the Cross Support Services (CSS) Area (reference [D12]).

The purpose of this Magenta Book is the production of a set of recommendations for facilitating interagency Delta-DOR operations that can both be useful now and evolve to meet future needs. The present document is intended to provide a set of standard practices to be used for setting up Delta-DOR measurements among different agencies, covering all of the required elements and describing how they are combined to provide the desired service.

1.2 SCOPE AND APPLICABILITY

Delta-DOR operations are applicable to space agencies that operate deep space missions that require accurate determination of the spacecraft position in the plane of the sky. For

operations where these requirements do not capture the needs of the participating agencies, Delta-DOR operations may not be appropriate.

This Recommended Practice addresses rationale, requirements and criteria that Delta-DOR operations processes should be designed to meet.

1.3 CONVENTIONS AND DEFINITIONS

Conventions and definitions of Delta-DOR concepts are provided in reference [D2], *Delta-DOR Operations—Technical Characteristics and Performance*. This reference provides a detailed description of the Delta-DOR technique, including guidelines for DOR tone spectra, guidelines for selecting reference sources, applicable foundation equations, and a discussion of error sources and measurement accuracy that are not germane to the recommendations presented in this document.

The following conventions apply throughout this Recommended Practice:

- 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.

1.4 COMMON DELTA-DOR TERMINOLOGY

Part of the standardization process involves the determination of common interagency terminology and definitions that apply to interagency Delta-DOR. The following conventions apply throughout this Recommended Practice:

Term	Meaning
baseline	The vector joining two tracking stations
channel	A slice of the frequency spectrum that contains a spacecraft or quasar signal
scan	An observation of a radio source, typical duration of a few minutes
spanned bandwidth	The widest separation between downlink signal components
P_T/N_0	Total Power to Noise Spectral Density ratio
P_{Tone}/N_0	Tone Power to Noise Spectral Density ratio
meteo data	Meteorological Data (as a minimum: pressure, temperature, relative humidity must be considered; slant total electron content might also be provided)

1.5 STRUCTURE OF THIS DOCUMENT

In addition to this section, this document contains the following sections and annexes:

- Section 2 provides a general overview of Delta-DOR technique.
- Section 3 provides a set of definitions for the interagency Delta-DOR.
- Section 4 describes the Delta-DOR interoperability scenarios.
- Section 5 discusses the interagency Delta-DOR validation process.
- Section 6 discusses the interagency data exchange products and procedures.
- Section 7 discusses the generation and maintenance of the radio source catalog.
- Annex A lists a number of items that should be covered in an interagency Implementing Arrangement (IA) prior to commencing regular Delta-DOR operations. There are several statements throughout the document that refer to the necessity of such a document; this annex consolidates all the suggested IA items in a single list in the document.
- Annex B discusses security considerations applied to the technologies specified in this Recommended Practice.
- Annex C is a list of abbreviations and acronyms applicable to Delta-DOR Operations.
- Annex D contains a list of informative references.

1.6 REFERENCES

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

- [1] *Radio Frequency and Modulation Systems—Part 1: Earth Stations and Spacecraft.* Recommendation for Space Data System Standards, CCSDS 401.0-B-20. Blue Book. Issue 20. Washington, D.C.: CCSDS, April 2009.
- [2] *Orbit Data Messages.* Recommendation for Space Data System Standards, CCSDS 502.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, November 2009.
- [3] *Tracking Data Message.* Recommendation for Space Data System Standards, CCSDS 503.0-B-1. Blue Book. Issue 1. Washington, D.C.: CCSDS, November 2007.

- [4] *Delta-DOR Raw Data Exchange Format*. Draft Recommendation for Space Data System Standards, CCSDS 506.1-R-1. Red Book. Issue 1. Washington, D.C.: CCSDS, April 2011.
- [5] “Radio Source Catalog.” May 26, 2006. Module 107 in *DSN Telecommunications Link Design Handbook*. DSN No. 810-005, Rev. E. Pasadena California: JPL, <<http://eis.jpl.nasa.gov/deepspace/dsndocs/810-005/>>

NOTE – Informative references are provided in annex D.