Deep Space Network

103
Tracking Services

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Document Change Log

Rev	Issue Date	Prepared By	Affected Paragraphs	Change Summary
Initial	01/12/2018	Dong Shin	All	This document supersedes D-19892, 810-007-104, Initial Release, as part of the new structure of the 810-007 document series.

Table of Contents

Section 1
Introduction

1.1 PURPOSE

This document describes the capabilities, data flow and interfaces, and operations provided by the Deep Space Network (DSN) Tracking Services for all missions using the DSN.

The DSN Tracking Services provide the measurement data that enables the mission to establish and maintain knowledge of spacecraft position and motion. The measurement data includes angle, delta Differential One-way Range (delta-DOR), Doppler, and ranging measurements.

1.2 REVISION AND CONTROL

This document is maintained by DSN System Engineering and will be revised to reflect new capabilities as those capabilities become approved by the DSN Project Office.

This document is approved for publication under the authority of the cover page signatories. Revisions are indicated by a revision letter following the module designator. Changes are appropriately marked and recorded in a Change Log at the front of this document.

This document is primarily concerned with the ground data and interfaces between flight projects and the DSN. It is principally organized around the DSN Service Catalog [1] and includes references to DSN external interface specifications [3] through [5].

Documents controlling this version include:

[1] 820-100 JPL D-30531 *Deep Space Network Services Catalog*

1.3 RELATIONSHIP TO OTHER SERVICES

Other than the DSN Tracking Services provided measurement data, accurate navigation requires ancillary data that include platform parameters and media, and timing calibrations. These calibration and modeling services are described in DSN document 810-007, Module 104 [11], Calibration and Modeling Services.

The DSN Tracking Services are requested and controlled through the Service Management (SMS) system, which performs the following functions:

- Allocation and scheduling of resources and assets
- Generates and delivers support products
- Service execution including the configuration and monitor and control of DSN assets
- Reporting of service execution results including performance

This document does not address the role and mission interface for the SMS that are required for obtaining the DSN Tracking Services.

1.4 CCSDS COMPLIANCE

The DSN Tracking Service is compliant with Consultative Committee for Space Data Systems (CCSDS) standards CCSDS 503.0-B-1 Tracking Data Message [2] for delivering angle, delta-DOR, Doppler, and ranging data to the Jet Propulsion Laboratory (JPL) navigation or other space agencies.

1.5 TERMINOLOGY AND NOTATION

Abbreviations and acronyms used in this document are defined with the first textual use of the term. Appendix A contains a list of abbreviations and acronyms used in this document. The definitions provided here are intended to clarify the use of certain terms as they apply to this module.

Deep Space Station (DSS)	A DSS is the specific antenna or antennas used to support a tracking session.
Mission	Flight project teams including project navigation, the flight operations, project sequence team, project scheduler
Mission Interface Manager (MIM)	DSN manager who is responsible for DSN interface to customer
Observable	Measurements provided by the DSN
Validated delta-DOR Data	Conditioned delta-DOR data with validation
Validated Radio Metric Data	Validation of erroneous configuration, subsystem status, performance measurements, measurement validity

1.6 REFERENCE DOCUMENTS

[2]	CCSDS 503.0-B-1	Blue Book	*Tracking Data Message (TDM)*
[3]	820-013, JPL D-76488	TRK-2-34	*Deep Space Network External Interface Specification, DSN Tracking System, Data Archival Format*
[4]	820-013, JPL D-16765	0212-Tracking-TDM	*DSN Tacking Data message (TDM) Interface*
[5]	820-013 JPL D-76491	0230-ServiceMgmt-DOR	*DOR Inputs to Project Scheduling and Sequencing*
[6]	810-005	Module 104	*DSN Telecommunications Link Design Handbook, 34-m BWG Stations Telecommunication Interfaces*

[7]	810-005	Module 202	*DSN Telecommunications Link Design Handbook, 34-m and 70-m Doppler*
[8]	810-005	Module 203	*DSN Telecommunications Link Design Handbook, Sequential Ranging*
[9]	810-005	Module 210	*DSN Telecommunications Link Design Handbook, Delta Differential One-way Ranging*
[10]	810-005	Module 214	*DSN Telecommunications Link Design Handbook, Pseudo-Noise and Regenerative Ranging*
[11]	810-007 JPL D-81591	Module 104	*Calibration and Modeling Services*
[12]	810-007 JPL D-81599	Module 203	*Emergency Control Center (ECC) Capabilities and Services Support*

Section 2
Services Description

2.1 INTRODUCTION

This section describes the DSN tracking services that enable a mission to establish and maintain knowledge of spacecraft line-of-sight position and velocity. Doppler and range measurements can also be used by radio science to model gravity fields, to determine the mass and rotation rates of planets, satellites, asteroids and other bodies, to search for evidence of gravitational radiation, and to study the transmission media (e.g., the solar corona).

DSN tracking services include delivery of: Radio Metric data (Doppler and ranging), delta-DOR data and angle data. The DSN also supports both coherent (2/3-way) and non-coherent (1-way) Doppler modes.

2.2 RADIO METRIC DATA

The DSN provides validated Radio Metric data service. The validation includes:

- Detection of erroneous configuration
- Subsystem status
- Measurement validity
- Performance measurements

The validation service includes correction of erroneous configuration, status, and calibration data. If the validation fails, then the data will not deliver to the mission. The capabilities and limitations of the equipment used for Doppler and range measurements are specified in DSN Document 810-005, Module 202 [7] for Doppler, 203 [8] for sequential ranging, and 214 [10] for Pseudo-Noise (PN) ranging, respectively.

2.2.1 Doppler Data

The DSN system measures the relative motion between the spacecraft and tracking station and provides the range rate information in both phase and frequency quantities. Note that phase data is only available in TRK-2-34 format [3].

2.2.1.1 Key Parameters

Doppler data contains measurement of the downlink carrier. Key parameters include:

- Measured downlink phase and frequency
- Downlink signal characteristics and acquisition status
- Uplink signal characteristics (2/3-way mode only)
- System configuration and status
- Deep Space Station (DSS) dependent parameters

2.2.2 Non-coherent Doppler Data

The DSN supports non-coherent Doppler mode and provides the range rate information in in both phase and frequency quantities. Note that phase data is only available in TRK-2-34 format [3].

2.2.2.1 Key Parameters

Doppler data contains measurement of the downlink carrier, and key parameters include:

- Measured downlink phase and frequency
- Downlink signal characteristics and acquisition status
- System configuration
- DSS dependent parameters

2.2.3 Ranging Data

The DSN ranging system measures the round-trip time delay of a ranging signal transmitted from the DSN to a spacecraft through a propagation medium and back to the DSN. The measured two-way delay permits the determination of the Round-Trip Propagation Time (RTPT) between the DSN and spacecraft.

Range measurements can be done using either sequential or Pseudo-random Noise (PN) ranging techniques. Both techniques are employed in the same set of DSS using the same instrumentation and provide similar results. However, there are performance differences between these two techniques, and they are documented in reference document for the sequential technique [8] and for the PN technique [10].

2.2.3.1 Sequential Ranging

The sequential ranging signal is generated from a sequence of periodic signals. These sequential signals are all coherently generated from the uplink carrier signal and proportionally related to each other in frequency. The received ranging signal is correlated with a local model of the uplink ranging signal to determine the round-trip phase delay. The correlation process can resolve range to a value that is modulo the period of the ranging code.

2.2.3.2 PN Ranging

The PN ranging signal is generated from a logical combination of the range clock and several PN codes. These PN signals are all coherently generated from the uplink carrier signal. The received ranging signal is correlated with a local model of the range clock and each of the individual PN codes that is a component of the signal. The correlation process can resolve range to a value that is modulo the period of the ranging code.

2.2.3.3 Key Parameters

Ranging data contains measurements of the uplink and downlink ranging phase. Key parameters include:

- Range observable (uplink ranging phase – downlink ranging phase – range correction)
- Downlink ranging phase
- Uplink ranging phase
- Downlink signal characteristics and acquisition status
- Computed Differenced Range Versus Integrated Doppler (DRVID)
- DSS delay calibration values
- System configuration
- DSS dependent parameters

2.3 DELTA-DOR DATA

Delta-DOR measurement is complementary to Doppler and range measurements to enable accurate spacecraft navigation. Delta-DOR service accurately measures the plane-of-sky position of the spacecraft. The DSN system measures spacecraft angular position in the radio reference frame by cross-correlating signals received by two (2) tracking stations.

The capabilities and limitations of the equipment used for delta-DOR measurement are specified in DSN Document 810-005, Module 210 [9].

2.3.1 Key Parameters

Delta-DOR data contains measurement of the spacecraft angular position. Key parameters include:

- Spacecraft and quasar interferometric delays
- Quasar ID
- Clock offset between DSS
- Data Validity
- System configuration information
- DSS dependent parameters

2.4 ANGLE DATA

Angle data is provided for first time acquisition of a spacecraft due to uncertainty in launch operations, predictions, and the dynamics of the spacecraft trajectory during Launch and Early Orbit Phase (LEOP). The Beam Waveguide 1 (BWG-1) antenna subnet (DSS-24, -34, -54) is the only subnet with co-located X-band acquisition aid antennas and capable of providing angle data.

2.4.1 Key Parameters

Angle data contains measurement of the antenna angular position. Key parameters include:

- Angle measurement
- Angle mode/type

- Data Validity
- System configuration information
- DSS dependent parameters

Section 3
Services Interfaces

This section describes mission interfaces to the DSN; data types the DSN delivers to the mission, required deliverables the mission must submit to the DSN in order to obtain tracking services. This section also describes the emergency contingency plan for the DSN tracking services if a natural disaster or other catastrophic event occurs as described in section 3.3.

Mission Interface Manager (MIM) is responsible for working with the mission to determine what data interfaces will be used by the mission.

3.1 MISSION-TO-DSN

The missions are required to deliver the DSN Schedule Request used to reserve and allocate the DSN resource for tracking support, the DSN Keyword File (DKF) describing the sequence of operation for each tracking pass, and the Spacecraft Ephemeris describing position and velocity of a spacecraft at multiple epochs contained within a specified time range.

3.2 DSN-TO–MISSION

This section describes DSN data deliverables to the mission.

3.2.1 Interface Details

This section lists the DSN products deliverables to the mission.

3.2.1.1 Interface Specification Documents

The interface, format, and data contents of each deliverable are documented in the following DSN interface specification documents:

3.2.1.1.1 TRK-2-34

Tracking data received from the Deep Space Communications Complex (DSCC) is processed, validated, and corrected at JPL. These validated and corrected data are conditioned into the TRK-2-34 [3] format products. TRK-2-34 [3] formatted data delivery is available to customers as files, stream-type queries, or broadcast streams.

3.2.1.1.2 0212-Tracking-TDM

Tracking data received from the DSCC is processed, validated, and corrected at the JPL. These validated and corrected data are conditioned into the CCSDS compliant 0212-Tracking-TDM [4] format. 0212-Tracking-TDM [4] formatted data delivery is available to customers as files.

3.2.1.1.3 0230-ServiceMgmt-DOR

The DSN engineering team provides delta-DOR tracking schedule and sequence of operation files per DSN interface module 820-013, 0230-ServiceMgmt-DOR [5].

A schedule file contains all observation opportunities for delta-DOR measurements including lists of the quasars observation and the mutual DSS view period begin/end times. A sequence of operation file contains detailed spacecraft and quasar identifier and observation times for each tracking pass.

3.2.1.2 Delivery Mechanism

The DSN delivers tracking data in near real-time and/or non real-time via file format. The DSN delivers one tracking pass per file for automated deliveries and also supports mission data requirements with respect to frequency of file delivery and number of tracking passes per data file for manual deliveries.

3.2.1.2.1 Real-Time Data Delivery

The DSN delivers TRK-2-34 [3] formatted Radio Metric data and angle data in near real-time within 5-second latency from the time tag of the measurement at the DSCC. The data delivery protocols are User Datagram Protocol (UDP) and can be either unicast or multicast mode.

3.2.1.2.2 Non Real-Time File Delivery

The file transfer protocols are Secure File Transfer Protocol (SFTP).

TRK-2-34 [3] or 0212-Tracking-TDM [4] formatted Radio Metric, delta-DOR data, and angle data per can be obtained through a DSN server at oscarx.fltops.jpl.nasa.gov, where access is restricted to authorized users. The access is dependent on the proper configuration and availability of DSN flight operations and JPL networks. The customer obtains the access authorization through MIM. The DSN accommodates a file delivery schedule based on scheduled passes on spacecraft activities.

Note that a total latency of the delta-DOR data delivery to data transfer from tracking station, correlation, and analysis is within 24 hours. The latency applies to business day cycle.

3.2.1.3 Supported Data Type

3.2.1.3.1 Validated Radio Metric Data

The DSN file delivery supports either TRK-2-34 [3] or 0212-Tracking-TDM [4] formatted data for validated metric data. The file can be obtained through the DSN server at oscarx.fltops.jpl.nasa.gov, where access is restricted to authorized users.

3.2.1.3.2 Validated Delta-DOR Data

The DSN file delivery supports either TRK-2-34 [3] or 0212-Tracking-TDM [4] formatted data for delta-DOR data. The file can be obtained through the DSN server at oscarx.fltops.jpl.nasa.gov, where access is restricted to authorized users.

3.2.1.3.3 Validated Angle Data

The DSN file delivery supports either TRK-2-34 [3] or 0212-Tracking-TDM [4] formatted data for validated angle data. The file can be obtained through the DSN server at oscarx.fltops.jpl.nasa.gov, where access is restricted to authorized users.

3.3 AVAILABILITY IN CONTINUITY OF OPERATION PLAN (COOP) ENVIRONMENT

The DSN Emergency Control Center (ECC) will provide continued spacecraft tracking operations during a natural disaster or other catastrophic event occurrence disables JPL facilities, which provides the interfaces for control, data delivery, and monitoring/supporting of spacecraft tracking activities.

The DSN ECC will provide following tracking data delivery support:

- TRK-2-34 [3] formatted real-time data delivery for Radio Metric data
- Non real-time file delivery of TRK-2-34 [3] and 0212-Tracking-TDM [4] formatted data for both Radio Metric data.

The DSN COOP provides the plans and tools needed to ensure continued spacecraft tracking operations as described in 810-007, Module 203 [12].

Appendix A - Abbreviations

CCSDS	Consultative Committee for Space Data Systems
COOP	DSN Continuity of Operations
DKF	DSN Keyword File
DRVID	Differenced Range Versus Integrated Doppler
DSCC	Deep Space Communications Complex
DOR	Differential One-way Range
DSN	Deep Space Network
DSS	Deep Space Station
ECC	Emergency Control Center
JPL	Jet Propulsion Laboratory
LEOP	Launch and Early Orbit Phase
MIM	Mission Interface Manager
PN	Pseudo-random Noise
RTPT	Round-Trip Propagation Time
SFTP	Secure File Transfer Protocol
SMS	Service Management
SPS	Service Preparation Subsystem
TDM	Tracking Data Message
UDP	User Datagram Protocol