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Radio Science Predicted and Reconstructed Orbit and Planetary Constellation Data: Specifications

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ACRONYMS

A/D	Analog/Digital
AGC	Automatic Gain Control
AGVTP	Archive Generation, Validation and Transfer Plan
AOL	Amplitude Open Loop
ATDF	Archival Tracking Data Format
CD-ROM	Compact Disk - Read Only Memory
CL	Closed-Loop
DDS	Data Delivery System
DSN	Deep Space Network
DVD	Digital Versatile Disk
ESA	European Space Agency
ESOC	European Space Operation Center
ESTEC	European Space Technology Center
FD	Flight Dynamics
FOL	Frequency Open Loop
G/S	Ground Station
HGA	High Gain Antenna
IFMS	Intermediate Frequency Modulation System
JPL	Jet Propulsion Laboratory
LCP	Left Circular Polarization
LGA	Low Gain Antenna
LOS	Line Of Sight
MaRS	Mars Express Radio Science Experiment
MGA	Medium Gain Antenna
MGS	Mars Global Surveyor
NASA	National Aeronautics and Space Administration
ODR	Original Data Record
OL	Open-Loop
ONED	one-way dual-frequency mode
ONES	One-way single-frequency mode
PDS	Planetary Data System
POL	Polarization Open Loop
RCP	Right Circular Polarization
RSR	Radio Science Receiver
RX	Receiver
S/C	Spacecraft

SIS	Software Interface Specification
S-TX	S-Band Transmitter
SPICE	Space Planet Instrument C-Matrix Events
TBC	To Be Confirmed
TBD	To Be Determined
TTCP	Telemetry, Tracking and Command ProcessorTWOD Two-way dual-frequency mode
TWOS	Two-way single-frequency mode
USO	Ultra Stable Oszillator
X-TX	X-band Transmitter

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1 INTRODUCTION

1.1 SCOPE

This document specifies the requirements for orbit prediction and reconstruction, the file content and format of the orbit predict file generated at UniBw München.

The predict file and the reconstructed radio science orbit file is used as the input for the radio science processing software (Doppler and Range) level 1b to level 2, and for the data analysis software level 3.

1.2 REFERENCED DOCUMENTS

	Reference Number	Title	Issue Number	Date
[1]	MEX-MRS-IGM-IS-3016	Radio Science File naming Convention	6.6	12.02.2004
[2]	MEX-MRS-IGM-DS-3035	IFMS/TTCP Doppler	2.3	12.02.2004
[3]	MEX-MRS-IGM-DS-3036	IFMS/TTCP range	1.6	12.02.2004
[4]	MEX-MRS-IGM-DS-3037	ODF Level 1a to level 1b		12.02.2004
[5]	MEX-MRS-IGM-DS-3038	ODF Level 1b to level 2		12.02.2004
[6]	VEX-VeRa-UBW-TN-3040	Time standards and reference frames		

1.3 DOCUMENT OVERVIEW

Section 2 defines general and particular specifications of predicted and reconstructed orbit data and the planetary constellation data
Section 3 defines file names and file formats

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2 GENERAL SPECIFICATIONS

2.1 DEFINITION OF CONSTANTS

PRED-DEF-1010: ASTRONOMICAL UNIT (AU)

1 AU = 149,597,870 km

Reference: Strauss, B., Highsmith, D., Mars Exploration Rover Project Planetary Constants and Models, Jet Propulsion Laboratory, Interoffice Memorandum, IOM 312/015-02, 2002

PRED-DEF-1015: SOLAR RADIUS (R_o)

1 R_o = 696,000 km

PRED-DEF-1020: SPEED OF LIGHT

c = 299,792,458 m/s

PRED-DEF-1030: CARRIER FREQUENCIES Mars Express, Venus Express, Rosetta

frequency band	uplink	downlink
S-band	2114.676 MHz	2296.482 MHz
X-band	7116.936 MHz	8420.432 MHz

PRED-DEF-1031: Transponder constants and ratios

frequency band uplink	transponder ratios downlink/uplink	
	S-band	X-band
S-band	240/211	880/211
X-band	240/749	880/749

2.2 SPECIFICATIONS: ORBIT PREDICTION AND RECONSTRUCTION FILES

PRED-SPEC-2210: PREDICT_FILE covers

- For the cruise phase: eight days of data. The last day of this predict file starting at 00:00:00 UTC is the first day of the sequentially following next predict file. Time periods covered by the predict files for the cruise phase are
  - from DOY 177 – 205
  - from DOY 288 – 295

- For the orbit phase eight days of data. The last day of this predict file starting at 00:00:00 UTC is the first day of the sequentially following. The predict data for the orbit phase starts at 2004-01-13T19:00:00 UTC.

PRED-SPEC-2220: Predicts or orbit reconstruction data shall be provided with maximum steps of ten minutes for the interplanetary cruise phase. Predicts or orbit reconstruction data shall be provided with steps of approximately 0.3 degree in true anomaly along the planetary orbit.

PRED-SPEC-2230: the predict data shall consider all necessary perturbing forces acting on the spacecraft. The predict data are build from the FD data containing state vectors of the orbit from ESOC, therefore the considered perturbing forces depend on the perturbing forces considered in the FD data

PRED-SPEC-2240: deleted

PRED-SPEC-2250: the following parameters shall be predicted or reconstructed:

- the dimensionless uplink Doppler shift $\frac{\Delta f}{f_{transmitted}}$, where $f_{transmitted}$ is the uplink transmitted frequency by the ground station
- the dimensionless downlink Doppler shift $\frac{\Delta f}{f_{transmitted}}$, where $f_{transmitted}$ is the downlink transmitted frequency by the spacecraft.
- the one-way geometric range
- the two-way range, considering the light time
- the one-way downlink light time
- the two-way light time.

PRED-SPEC-2251: the predict or reconstructed data shall be computed using the relations described in VEX-VeRa-UBW-TN-30xx [reference 6].

PRED-SPEC-2260: the predict and reconstruction data shall ***not*** consider corrections concerning

- the Earth troposphere
- the Earth ionopshere
- the interplanetary space
- planetary atmospheres and ionospheres
- the solar corona

2.3 SPECIFICATIONS: PLANETARY CONSTELLATION GEOMETRY FILE

PRED-SPEC-2310: coordinate system
The coordinate system is solar system barycentric. The specifications of the Earth Mean Equator System 2000 (EME 2000) shall be used.

PRED-SPEC-2320: constellations
Earth and planetary constellations of the following bodies shall be computed:

Spacecraft	Interplanetary body	sss
Mars Express	Mars	MAR
Venus Express	Venus	VEN
Rosetta	Steins	STE
Rosetta	Lutetia	LUT
Rosetta	Comet 67 P/Churyumov-Gerasimenko	P67

PRED-SPEC-2330: time coverage
Constellations shall be computed for a specific year covering the time span from 1st January to 31st January of the following year (13 months). The time step is one constellation coordinate per day at 12:00 UTC.

PRED-SPEC-2340:
The following values shall be computed:

- The three Cartesian components of the barycentric position vector of the Earth
- The three Cartesian components of the barycentric position vector of the planetary body
- The three direction angles
  - Sun-Earth-planetary body
  - Earth-Sun-planetary body
  - Sun-planetary body-Earth
- The solar offset of the planetary body in the plane of sky relative to the solar disk in solar radii (defined in PRED-DEF-1015).

3 FILE NAMES AND FILE FORMAT SPECIFICATIONS

3.1 ORBIT PREDICTION FILES

3.1.1 File name

PRED-SPEC-3110: The file name is defined as

rggUNBWL02_sss_yydddhhmm_qq.TAB

Table 2.3-1: file name Definition

placeholder	description	example
r	spacecraft name M = MEX R = Rosetta V = VEX	M
gg	Ground station ID: DSN complex Canberra 34 = 34 m BWG 43 = 70 m 45 = 34 m HEF ESA Cebreros antenna: 62 = 35 m DSN complex Goldstone: 14 = 70 m 15 = 34 m HEF 24 = 34 m BWG 25 = 34 m BWG 26 = 34 m BWG 27 = 34 m HSBWG ESA Kourou antenna xx = 15 m DSN complex Madrid: 54 = 34 m BWG 55 = 34 m BWG 63 = 70 m 65 = 34 m HEF ESA Malargüe antenna: 84 = 35 m ESA New Norcia antenna 32 = 35 m	32

tttt	Data source UNBW = UniBw München	UNBW
L02	Data level L02	L02
sss	File type PTW = predicted two-way data PON = predicted one-way data RTW = reconstructed two-way data RON = reconstructed one-way data	PTW
yy	year	03
ddd	day of year	180
hhmm	start time of data in hour, minute	2345
qq	not used	00
TAB	Extension .TAB data file	TAB

3.1.2 File Format

PRED-SPEC-3210: the file output is ASCII

3.1.2.1 Doppler and range predict files generated from long-term planning orbit file

column	description	unit	resolution
1	sample number	[-]	integer
2	Time stamp in ISO format (GRT)	[-]	1 sec
3	Fractions of DOY (GRT)	days	10^{-7} days
4	Seconds since 01.01.2000, 12h TDB (GRT)	days	10^{-8} sec
5	uplink Doppler $\frac{\Delta f}{f_{transmitted}}$	[-]	10^{-15} (17 digits)
6	one-way / downlink Doppler $\frac{\Delta f}{f_{transmitted}}$	[-]	10^{-15} (17 digits)
7	geometric range ($r_{SC}(t_{TWE})$ - $r_{GS}(t_{TWE})$)	km	10 m
8	two-way range; light-time corrected with rel. delay ($(r_{SC}(t_{TWRU})-r_{GS}(t_{TWE}))+((r_{GS}(t_{TWRD})-r_{SC}(t_{TWRU}))$)	km	10 m
9	downlink light-time (t_{TWRD} - t_{TWRU})	seconds	10^{-9} sec
10	two-way light-time (t_{TWRD} - t_{TWE})	seconds	10^{-9} sec
11	Ground Station Elevation at GRT	degree	10^{-2} degree

3.1.3

3.1.3.1 Doppler and range predict files generated from reconstructed orbit file

column	description	unit	resolution
1	sample number	[-]	integer
2	Time stamp in ISO format (GRT)	[-]	1 sec
3	Fractions of DOY (GRT)	days	10^{-7} days
4	Seconds since 01.01.2000, 12h TDB (GRT)	days	10^{-8} sec
5	uplink Doppler $\frac{\Delta f}{f_{transmitted}}$	[-]	10^{-15} (17 digits)
6	one-way / downlink Doppler $\frac{\Delta f}{f_{transmitted}}$	[-]	10^{-15} (17 digits)
7	geometric range ($r_{SC}(t_{TWE})$ - $r_{GS}(t_{TWE})$)	km	10 m
8	two-way range; light-time corrected with rel. delay ($(r_{SC}(t_{TWRU})-r_{GS}(t_{TWE}))+((r_{GS}(t_{TWRD})-r_{SC}(t_{TWRU}))$)	km	10 m
9	downlink light-time (t_{TWRD} - t_{TWRU})	seconds	10^{-9} sec
10	two-way light-time (t_{TWRD} - t_{TWE})	seconds	10^{-9} sec
11	Ground Station Elevation at GRT	degree	10^{-2} degree

Nomenclature:

UL uplink
DL downlink
c speed of light (c = 299,792,458 m/s)
LT Light time
v_{LOS} relative velocity between ground station and S/C (in the line of sight)
$r_{SC}(t)$ Position of S/C at time t
$r_{GS}(t)$ Position of ground station at time t

t_{TWE} Time at emission of signal at ground station
t_{TWRU} Time at reception of signal at S/C (uplink)
t_{TWRD} Time at reception of signal at ground station (downlink)

3.2 PLANETARY CONSTELLATION FILE

3.2.1 File Name

PRED-SPEC-3210: The planetary constelltion file name is defined as

r00UNBWL02_sss_yydddhhmm_qq.TAB

Table 3-1: Constellation file name Definition

placeholder	description	example
r	spacecraft name M = MEX R = Rosetta V = VEX	M
00	00 = valid for all ground stations	00
UNBW	Data source UNBW = UniBw München	UNBW
L02	Data level L02	L02
sss	File type See PRED-SPEC-2320	MAR
yy	year	03
ddd	day of year	180
hhmm	start time of data in hour, minute	2345
qq	not used	00
TAB	Extension .TAB data file	TAB

3.2.2 File Format

PRED-SPEC-3220: The file formats are defined as:

column	description	unit	resolution
1	Sample number		
2	Time in ISO format		
3	fractions of day of year	days	10^{-7} days
4	JD since 01.01.2000	JD	10 ms
5	x-component Earth r_{Ex}	AU	10^{-9} AU
6	y-component Earth r_{Ey}	AU	10^{-9} AU
7	z-component Earth r_{Ez}	AU	10^{-9} AU
8	x-component Planet r_{Px}	AU	10^{-9} AU
9	y-component Planet r_{Py}	AU	10^{-9} AU
10	z-component Planet r_{Pz}	AU	10^{-9} AU
11	angle Planet-Sun-EarthPSE	deg	0.1 deg
12	angle Sun-Earth-Planet SEP	deg	0.1 deg
13	angle Sun-Planet-EarthSPE	deg	0.1 deg
14	solar offset R	Solar radii	0.01 solar radii