GeoForschungsZentrum Potsdam
Stiftung des öffentlichen Rechts

S. Bedrich
F. Flechtner
Ch. Reigber

PRARE
Routine Operations Plan

Scientific Technical Report STR95/12

Imprint

GeoForschungsZentrum Potsdam

Department
Recent Kinematics and Dynamics of the Earth
Telegrafenberg A 17
D-14473 Potsdam

Printed in Potsdam
March 1995

A.1.2.2
PRARE

S. Bedrich, F. Flechtner, Ch. Reigber

PRARE
Routine Operations Plan

Scientific Technical Report STR95/12

03. April 1995

GeoForschungsZentrum Potsdam
95.0001
- Bibliothek -
STR 95/12
Telegrafenberg, 14473 Potsdam

Imprint

GeoForschungsZentrum Potsdam

Department
Recent Kinematics and Dynamics of the Earth
Telegrafenberg A 17
D-14473 Potsdam

Printed in Potsdam
March 1995

TABLE OF CONTENTS

1 SCOPE 1

2 THE PRARE SYSTEM 2
2.1 Main Characteristics 2
2.2 Measurement Principle 2
2.3 Data Flow and Data Handling 4
2.4 PRARE Ground Segment 4

3 PRARE DATA FLOW 8

4 MASTER STATION HARDWARE AND COMMUNICATION 10

5 GROUND STATION NETWORK OPERATIONS 10
5.1 Ground Station Announcement and Setup 10
5.2 Ground Station Activation 10
5.3 Ground Station Network Planning 11

6 CLOCK MODEL UPDATE 12
6.1 Space Segment Oscillator Monitoring 12
6.2 Clock Model Generation 13

7 COMMANDING 15
7.1 Commanding of PRD 15
7.2 Commanding of SIP 15
7.3 Commanding of Data Dumps 16

8 DECODING 17

9 FULL RATE DATA GENERATION 18
9.1 Corrections due to Measurement Principle 18
9.2 Additional Corrections 19

10 QUALITY CONTROL AND VALIDATION 21
10.1 Normal Point Generation 21
10.2 External Calibration 22
10.3 Calibration and Validation ofthe ERS-2 PRARE Ionospheric Product 22
10.3.1 Calibration using Common View Technique 22
10.3.2 Calibration Using Faraday Rotation Measurements 23

11 DATA ARCHIVING AND DISSEMINATION 25
11.1 Archiving and Dissemination at D-PAF Oberpfaffenhofen 25
11.2 Archiving and Dissemination at GFZ Potsdam Data Center 26

12 REPORTING 27

1 SCOPE

This document describes all routine operations of the ERS-2 PRARE Master Station, located at the GFZ/D-PAF Oberpfaffenhofen, which are necessary to coordinate the globally distributed Ground Station network, to operate the Timing System for clock model generation, to preprocess and archive the PRARE measurement data, and to generate commands for specific Space Segment operations.

Additionally, the maintenance of the PRARE Master Station hardware, the communication links, the quality control and validation of the tracking data, and the reporting are summarized.

2 THE PRARE SYSTEM

2.1 Main Characteristics

The PRARE (Precise Range and Range Rate Equipment) system is a German space-borne two-way two frequency microwave tracking system. It was developed and manufactured under grant of the Deutsche Agentur fuer Raumfahrtangelegenheiten (DARA) by the Institute for Navigation (INS), Stuttgart, Kayser Threde GmbH, Munich, Dornier GmbH, Friedrichshafen, and the GeoForschungsZentrum (GFZ), Potsdam.

PRARE performs highly precise range and range-rate measurements at sub-decimeter level of accuracy with the assistance of transportable, dedicated Ground Station transponders. It can be used for various applications in the field of orbit determination, geodesy, geophysics and atmospheric sciences.

The main characteristics of the PRARE links are given in table 2-1 below.

X-band downlink	8489 MHz 10 Mbits/sec BPSK (bandwidth 10 MHz) 2 (4) kbits/sec data transfer 1 watt transmit power
S-band downlink	2248 MHz 1 Mbits/sec BPSK (bandwidth 1 MHz) 1 kbits/sec data transfer 1 watt transmit power
Ground Station Transponder	60 cm parabolic dish 5 watts transmit power
X-band uplink	7225.296 MHz 10 Mbits/sec BPSK (bandwidth 10 MHz) 2 (4) kbits/sec data transfer
Satellite antennas	crossed dipoles at X- and S-band

Table 2-1: PRARE Main Characteristics.

2.2 Measurement Principle

The on-board equipment (mass 19 kg, power consumption 32 watts operational), dimension 400*240*180 mm^3) performs the two-way range and range-rate measurements in X-band.

Additionally, it transmits coherent signals in S-band for ionospheric error correcting purposes.

The ground stations are small, mobile units of moderate costs. At X-band they work as regenerative and coherent transponders, at S-band they represent receivers for the transmitted signals and perform measurements of the difference of the time of arrival of both signals which is the direct measure of the total electron content (TEC) along the transmission path.

The procedure to perform range and range-rate measurements is as follows:

Transmission of PN-coded X-band signals starts onboard as soon as the satellite is within the line of sight of the ground station (above 2 deg. elevation). After completion of the necessary acquisition phase the precise ranging begins (above 5 deg. elevation). The PN-coded signals are received and demodulated by the ground station, and the PN-sequence is remodulated by the ground transmitter (regenerative transponder). The cleaned signal is then sent back to the Space Segment.

The PRARE measurement precision is given in table 2-2 below.

Noise values	±1.5 cm rms for X-band ranging (1 measurem./sec) ±0.05 mm/sec rms for X-band Doppler (30 sec integr. time, 90° elevation)
Bias values	<1 cm for X-band, <3 cm for S-band (after post-proc.)
Range error estimation	tropospheric error = 2 ... 7 cm ionospheric error < 1 cm thermal noise and calibration error = 2 ... 3 cm antenna phase centre uncertainty < 1 cm
Total ranging accuracy	3 ... 7 cm rms (1 sec integr. time after pre-proc.)
Total range-rate accuracy	0.05 mm/sec rms (30 sec integr. time, 90° elevation)

Table 2-2: Measurement Precision of the PRARE System.

The transponders being at the same time coherent, the carrier frequency of the up-link is in a well-defined phase relationship to the down-link carrier frequency. On-board, the instrument is, therefore, able to measure both the two-way range and the received two-way Doppler-shifted signal very precisely by comparing the phase of the received signal to the phase of the on-board instrument clock. The overall accuray stems mainly from this two-way configuration of the measurement system which eliminates most clock error terms inherent to one-way systems.

Additionally, it transmits coherent signals in S-band for ionospheric error correcting purposes.

The ground stations are small, mobile units of moderate costs. At X-band they work as regenerative and coherent transponders, at S-band they represent receivers for the transmitted signals and perform measurements of the difference of the time of arrival of both signals which is the direct measure of the total electron content (TEC) along the transmission path.

The procedure to perform range and range-rate measurements is as follows:

Transmission of PN-coded X-band signals starts onboard as soon as the satellite is within the line of sight of the ground station (above 2 deg. elevation). After completion of the necessary acquisition phase the precise ranging begins (above 5 deg. elevation). The PN-coded signals are received and demodulated by the ground station, and the PN-sequence is remodulated by the ground transmitter (regenerative transponder). The cleaned signal is then sent back to the Space Segment.

The PRARE measurement precision is given in table 2-2 below.

Noise values	±1.5 cm rms for X-band ranging (1 measurem./sec) ±0.05 mm/sec rms for X-band Doppler (30 sec integr. time, 90° elevation)
Bias values	<1 cm for X-band, <5 cm for S-band (after post-proc.)
Range error estimation	tropospheric error = 2 ... 7 cm ionospheric error < 1 cm thermal noise and calibration error = 2 ... 3 cm antenna phase centre uncertainty < 1 cm
Total ranging accuracy	3 ... 7 cm rms (1 sec integr. time after pre-proc.)
Total range-rate accuracy	0.05 mm/sec rms (30 sec integr. time, 90° elevation)

Table 2-2: Measurement Precision of the PRARE System.

The transponders being at the same time coherent, the carrier frequency of the up-link is in a well-defined phase relationship to the down-link carrier frequency. On-board, the instrument is, therefore, able to measure both the two-way range and the received two-way Doppler-shifted signal very precisely by comparing the phase of the received signal to the phase of the on-board instrument clock. The overall accuracy stems mainly from this two-way configuration of the measurement system which eliminates most clock error terms inherent to one-way systems.

For ionospheric error correction the PN-sequences of the X-band and the S-band receivers on-ground are demodulated. The 10 MHz PN-code of the down-link X-band is compared to the corresponding 1 MHz PN-code of the S-band. The time difference is a measure for the total electron content of the ionospheric path. For this reason the delay value is sent up to the satellite together with the meteorological data and the housekeeping values of the ground station.

2.3 Data Flow and Data Handling

The instrument performs permanently and autonomously all data dissemination to manage the operations of the ground station network and the on-board data storage of all science and housekeeping data. All measurements are time tagged to a well monitored on-board clock. The data are dumped to the PRARE Master Station during overflight via the X-band down link.

Preprocessing of the dump data at the Master Station takes into account all influences which are known concerning the on-board instrument, the transmission path, the ground station transponders, the measurement principle itself, the clock correction and calibration data. After data pre-processing the data will be offered to the users of the system in standardised form.

2.4 PRARE Ground Segment

The PRARE Ground Segment is made up of:

- transportable, globally distributed **Ground Stations** which operate as regenerative coherent transponders contributing to the Space-Ground-Space range and Doppler-shifted data for precise orbit and station position determination. Minor data transmission capabilities are included;

- a **Master and Command Station** at the D-PAF in Oberpfaffenhofen whose major tasks are:

  - uploading of station interogation plans (SIP), PRARE prediction elements (PRD), and dump commands for PRARE tracking and correction data,

  - reception of PRARE raw tracking and ionospheric refraction data from a global network of tracking stations dumped to the Master Station during every satellite contact,

  - decoding of this raw data by merging the raw data dumps into single passes, encoding the data into physical units and applying corrections due to H/W characteristics, measurement principle and internal calibration of the Space Segment,

- operating the PRARE Master Station Timing System which consists mainly of a GPS time receiver and a master Rubidium normal. During every contact with the PRARE Space Segment or with a GPS satellite, time comparisons are performed between the on-board clocks and the local Rubidium oscillator to generate a clock model PRARE time vs. international time UTC for monitoring the Space Segment oscillator and for precise time tagging of the observations,

- preprocessing of decoded single passes by calculation of several corrections for the decoded data (time tagging, troposphere, ionosphere, centre of mass, ground station mechanical centre, satellite phase centre and external calibration) and detection of outliers,

- generation of normal points from the pre-processed full rate observations,

- administration and coordination of the ground station network - consisting of 29 ground stations - in close contact with the different user groups. The station announcement sheet has a standard form and is converted into a station activity file (SAF) and a station interrogation plan (SIP),

- archiving and dissemination of the PRARE products to the PRARE ground station owners, which is done using DMS and the FTP server at the D-PAF for ionospheric products and UNITREE and the FTP server at GFZ in Potsdam for all other PRARE products;

- a **PRARE Monitor Station** in Stuttgart whose major task is the monitoring of all functions of the Space Segment using real time commanding procedures; and

- a **Calibration Station** at the GFZ in Potsdam where a permanent calibration with a third generation Laser system will take place for system verification and calibration purposes.

3 PRARE DATA FLOW

To include a PRARE ground station in the global tracking network the ground station owner has to sent a defined station announcement sheet to the PRARE Master Station with details about the location of the station (coordinates), the tracking schedule and other site specific information. This announcement will be included in the station activity file and the station will be activated in the Space Segment by a command uploaded at the Master Station.

Additionally a set up file containing current PRARE prediction elements for the first initialisation will be generated and sent to the user where this information has to be loaded to the ground station processor. Both, the announcement and the set up file, are routed through the telecommunication system (TCS) services at the D-PAF or by FAX.

As soon as the the Space Segment and the ground station are initialised the tracking starts and the data are stored in the onboard memory. At each contact of the satellite with the Master Station the content of the memory is downloaded. These raw data are decoded and preprocessed to generate PRARE products in a defined ASCII coded format.

The GFZ POD team at the D-PAF generates on a routine basis predicted orbits which are used to upload PRARE elements to the Space Segment. The preliminary orbits containing Laser, Altimeter, and PRARE data are used to generate PRARE normal points to be included in POD for ERS-2.

All PRARE products are transmitted via Internet to the GFZ Potsdam Data Center (GFZ/DC) for archiving and dissemination to the users. The PRARE ionospheric product will also be archived and disseminated through the database managment system (DMS) at the D-PAF.

The main PRARE data flow is described in figure 3-1.

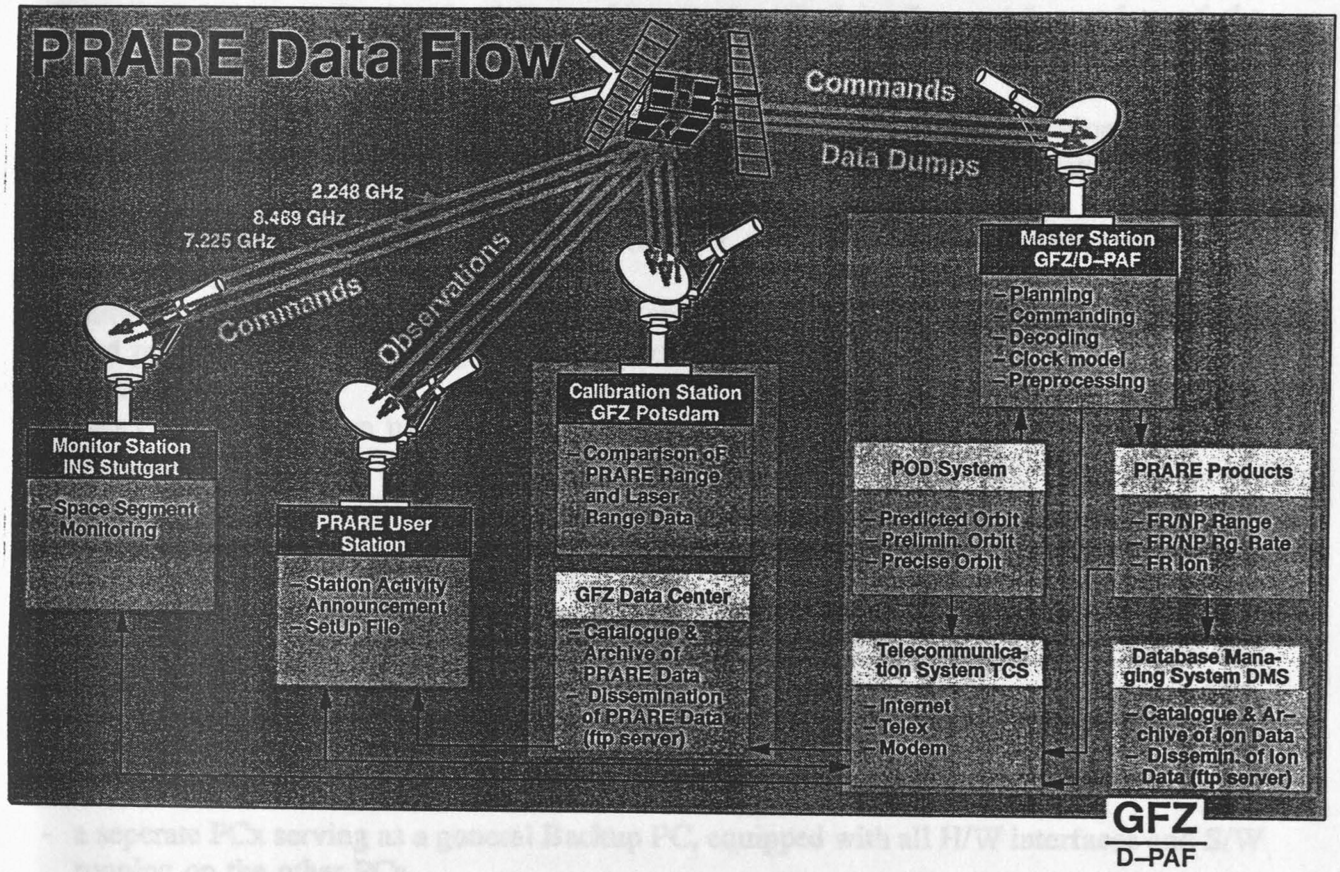

Figure 3-1: PRARE Data Flow.

4 MASTER STATION HARDWARE AND COMMUNICATION

The PRARE Master Station hardware which is described in figure 4-1 consists of the following components:

- a PRARE ground station with Monitor & Test Computer for the reception of 2 kb/s PRARE raw data dumps and time signals and for the generation of tracking data if the station is activated in the Space Segment,
- a timing system consisting of a GPS time receiver, a Rubidium normal, and a time interval counter (for details refer to chapter 6),
- three workstations prare, prare2, and gfz4 for generation of PRARE prediction elements and preprocessing of tracking data (each workstation can serve as a backup for the other ones),
- two PC6a/b which are used for the Space Segment commanding and 4 kb/s data dump reception,
- one PC5 for the generation of the clock models onboard time scale vs. UTC,
- one PC4 which is used for the decoding of raw data dumps and the daily planning of the mission,
- two PC1/3 which are used for software development and backup purposes,
- a second PRARE ground station which is permanently used in a passive mode; in case of problems at the main ground station this second station will be used as a backup solution,
- a dual-frequency GPS ROGUE receiver which is used to monitor permanently the ionosphere for system verification and calibration with a connected PC2 for data transfer to the GFZ IGS data centre,
- a seperate PCx serving as a general Backup PC, equipped with all H/W interfaces and S/W running on the other PCs.

All components are controlled each day.

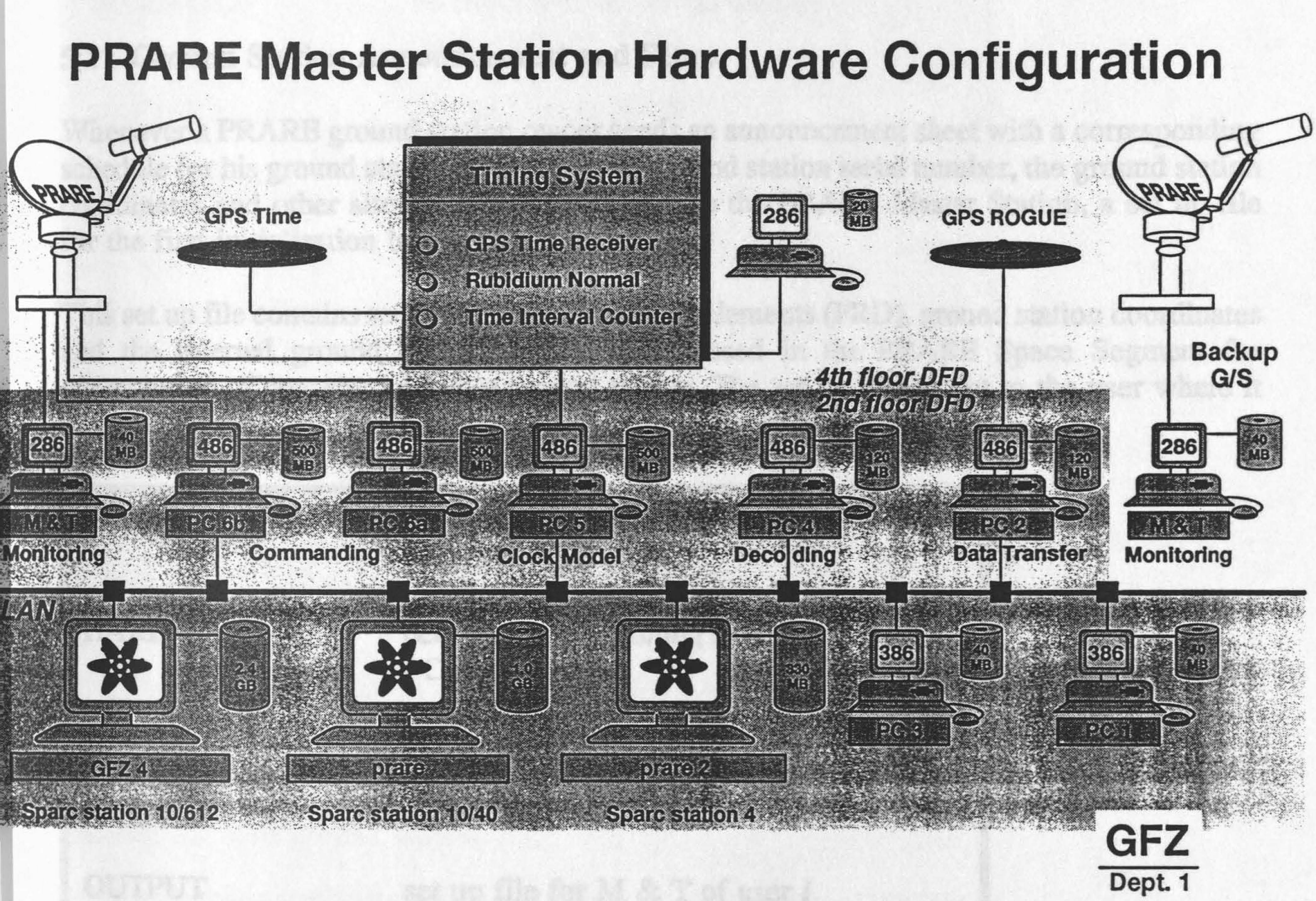

Figure 4-1: PRARE Master Station Hardware.

5 GROUND STATION NETWORK OPERATION

5.1 Ground Station Announcement and Setup

Whenever a PRARE ground station owner sends an announcement sheet with a corresponding schedule for his ground station activation, the ground station serial number, the ground station coordinates and other site specific informations to the PRARE Master Station, a set up file for the first initialisation has to be generated.

This set up file contains recent PRARE prediction elements (PRD), ground station coordinates and the internal ground station number being used in the PRARE Space Segment for computation of contacts with that ground station. The set up file is sent to the user where it has to be loaded into the ground station monitor & test computer (M&T).

SCHEDULE	on request of user *i* via station announcement sheet
HARDWARE	decoding and planning PC4 (or Backup PCx)
SOFTWARE	planning S/W
INPUT	station announcement sheet
OUTPUT	set up file for M & T of user *i*

5.2 Ground Station Activation

Additionally the user ground station announcement information is added to the station activity file (SAF) of the PRARE Master Station. In this file all ground station specifications (like activation/deactivation times, station coordinates, internal IDs) are stored which are needed to decode and preprocess the data.

SCHEDULE	on request of user *i* via station announcement sheet
HARDWARE	SPARCstation 10/40
SOFTWARE	manual update
INPUT	station announcement sheet
OUTPUT	updated station activity file SAF

5.3 Ground Station Network Planning

On a daily basis the PRARE station interrogation plan (SIP) stored in the Space Segment has to be controlled to avoid data storage problems in the onboard memory. With the SIP all station operations are managed (activation/deactivation, visibility limitations).

The planned ground station network configuration and the current orbit are used to calculate theoretical contacts with the Space Segment for the planning period (the next days of the mission). Dependent on the available onboard storage ground stations might have to be restricted in visibilities or even deactivated. Additionally the respective PN code has to be defined for each ground station.

SCHEDULE	daily
HARDWARE	decoding and planning PC4 (or Backup PCx)
SOFTWARE	planning S/W
INPUT	station activity file SAF, PRARE prediction elements PRD
OUTPUT	station interogation plan SIP

6 CLOCK MODEL UPDATE

The main objective of the PRARE Timing System operated at the Master Station is to provide a clock model which describes the behaviour in time of the PRARE Space Segment oscillator.

As all system frequencies as well as all time interval measurements are derived from one single oscillator, the PRARE Space Segment USO (ultra-stable oscillator), it has to be monitored carefully in order to maintain measurement coherency. This way, Doppler (frequency) and range (time interval) as well as the measurement data's time tagging are based on the same beat, which is a requirement of overall system stability.

6.1 Space Segment Oscillator Monitoring

Monitoring of the PRARE on-board oscillator is fulfilled by the system Master Clock housed at GFZ/D-PAF, a Rubidium standard in phase-lock redundancy (main and spare clock). The PRARE Space Segment time signals, which consist of coded 1-pps information contained in the data stream, are decoded by the ground station processor during satellite contacts and forwarded to the timing system. A high quality Time Interval Counter compares these signals with the 1-pps signals coming from the Rb-clock. The TIC is activated and read out by a dedicated laptop computer, the On-line Computer, which is integrated in the time system rack and running a specific measurement program.

Time offset, drift, and ageing of the Rb-master clock against UTC are determined permanently by comparison with the UTC informations derived from a high quality GPS time receiver. Operating fully autonomously, it decodes regularly (every 1 or 2 hours) during 20 minutes the time signals which the various GPS satellites transmit down. In a follow-on process they are reduced to a second degree polynomial fit in order to reduce the degrading effects the GPS Selective Availability operations impose. Additionally, minor Master Clock corrections which become necessary in aperiodic intervals are steered every three days by a DCF77 receiver which receives precise time information from the Physikalisch-Technische Bundesanstalt (PTB) at Braunschweig.

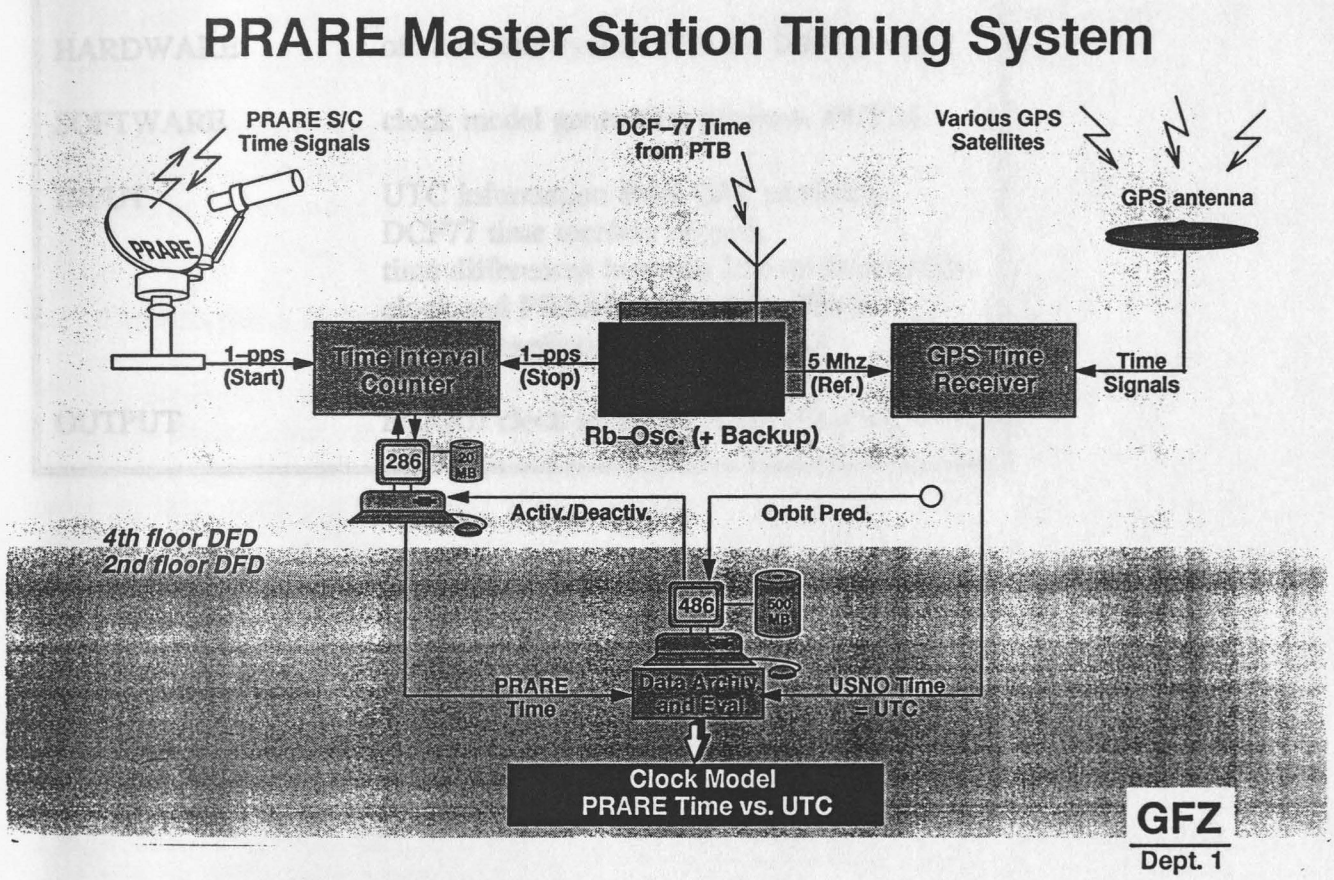

Figure 6-1: Components of the PRARE Timing System and Systematic Data Flow.

6.2 Clock Model Generation

Correction of the PRARE time signals, evaluation of the difference measurements, correction for hardware calibration biases, and referencing the measurements to UTC is done on a second computer, the Off-line Computer installed in the PRARE operations room. A program which involves predicted satellite orbit elements provided by the D-PAF orbit group yields on-board time offset, time drift (= frequency offset), and oscillator ageing (= frequency drift). These parameters represent the PRARE system clock model. It is updated at least every three days evaluating all measurements taken during previous satellite passes which are longer then 10 minutes (at least 5 a day).

The clock model allows to time tag all system range and Doppler measurements to UTC with an accuracy of about 1 µs. It is transported via floppy disk to the PRARE decoding PC and SPARCstation prare for further tracking data processing.

SCHEDULE	every three days (at the latest)
HARDWARE	off-line time system PC5 (or Backup PCx)
SOFTWARE	clock model generation program MCLM
INPUT	UTC information from GPS satellites, DCF77 time receiver signals, time differences between Master Station Rb-clock and PRARE onboard oscillator, PRARE prediction elements PRD
OUTPUT	PRARE clock model on-board time vs. UTC

7 COMMANDING

The PRARE network operation is controlled centrally through the Space Segment by commands given from the Master Station. Three commands will be performed:

- upload of PRARE prediction elements (PRD),
- upload of station interrogation plans (SIP),
- upload of commands for dumping PRARE tracking and correction data.

7.1 Commanding of PRD

PRARE predictions are used onboard to compute the next contact of the Space Segment with a Ground Station and are transmitted from the Space Segment to the Ground Station for steering the antenna unit. PRD will be generated by the GFZ/D-PAF orbit team on a routine basis (at least once per week) and after manoeuvres using most recent Laser and PRARE tracking data.

Whenever a new PRD set has been generated the PRARE team is informed by electronic mail. The calculated validity epoch is then changed to a moment of time when PRARE will not be in contact with any PRARE Ground Station to avoid acquisition problems in the Space Segment. This is realized by calculation of contacts with an artificial ground station in the Pacific Ocean where no other Ground Stations are planned at present.

The modified PRD will then be copied from the local network to the commanding PC where they will be uploaded automatically (after some consistency checks) to the Space Segment during next contact with the Master Station.

SCHEDULE	weekly or after manoeuvers
HARDWARE	commanding PC6 (or Backup PCx)
SOFTWARE	DATNEU/PRASIM
INPUT	PRARE prediction elements PRD
OUTPUT	PRD upload command

7.2 Commanding of SIP

With the SIP station operations are managed (c.f. chapter 5). The SIP will be generated on a daily basis taking into account the actual PRARE Ground Station Network and the satellite orbit.

The SIPs are transformed to commands for the Space Segment within the planning software. They will be copied to the commanding PC and uploaded automatically (after some consistency checks) to the Space Segment during next contact with the Master Station.

SCHEDULE	daily
HARDWARE	commanding PC6 (or Backup PCx)
SOFTWARE	DATNEU/PRASIM
INPUT	station interrogation plans SIP
OUTPUT	SIP upload command

7.3 Commanding of Data Dumps

With the dump command, downloading of the data stored in the onboard memory is initiated. This command is given automatically whenever the satellite passes over the Master Station (at least 5 times a day).

SCHEDULE	every pass at the Master Station
HARDWARE	commanding PC6 (or Backup PCx)
SOFTWARE	DATNEU/PRASIM
INPUT	dump command
OUTPUT	dumped PRARE raw data

8 DECODING

The tracking and corrective data stored in the onboard memory during contacts with PRARE Ground Stations will be available after dumping at the Master Station. These binary data have to be decoded in a first step into physical quantities like

- time tag (PRARE time scale),
- range,
- Doppler,
- Low Rate Byte (containing meteorological, calibration and ionospheric data of the Ground Station),
- AGC (Automatic Gain Control) values of the Space Segment receivers,
- temperature of the USO (Ultra Stable Oscillator), and
- number of channel which has observed range and doppler.

To decode PRARE raw data the following steps have to be performed:

- On a daily basis the dump data received on the commanding PC have to be copied to the PC where the decoding is performed.
- The clock model for transformation of the PRARE time scale vs. UTC has to be updated on the decoding PC whenever modified.
- The current station activity file where the corresponding activity times of the Ground Stations are stored (c.f. chapter 4) has to be updated on the decoding PC whenever modified.
- For calculation of theoretical range and doppler observations a (predicted) reference orbit is needed. This orbit is provided by the GFZ/D-PAF orbit team and has to be updated on a regular basis on the decoding PC.
- The decoding software has to be started, all data dumps found in the corresponding input directory are decoded file by file and the corresponding decoded quantities are written in a chronological form on a ASCII coded output file for each Ground Station.

SCHEDULE	daily
HARDWARE	decoding PC4 (or Backup PCx)
SOFTWARE	decoding software ANNA
INPUT	PRARE raw data dumps, clock model PRARE time vs. UTC, station activity file SAF, reference orbit
OUTPUT	chronologically decoded ASCII files of PRARE raw data for each ground station

9 FULL RATE DATA GENERATION

The decoded raw data are processed into PRARE Full Rate Data on a daily basis. These data serve for the generation of the predicted and precise orbits. The Full Rate Data product is an ASCII coded file for each data type (range, doppler, and ion) and each Ground Station seperately. The product generation is performed in several steps.

9.1 Correction due to Measurement Principle

In this step all corrections are calculated and applied to the raw measurements which are governed by the PRARE measurement principle. These are:

- solving for ambiguities of the range tracking data,
- correction for the doppler counter overflow,
- calculation of ionospheric, calibration and meteorological data by decoding of the low rate data,
- calculation of range corrections as a function of doppler shift, AGC value, and USO temperature,
- correction of range data due to onboard test transponder measurements.

The result are formatted chronological ASCII files for all observed passes which consist of the PRARE time tag, the corrected range and doppler data, the integration interval of the doppler data and the decoded low rate information. The input necessary for this step are the PRARE prediction elements PRD, the station activity file SAF, and the clock model of onboard time vs. UTC to correct for range ambiguities and doppler counter overflow.

SCHEDULE	daily
HARDWARE	SPARCstation 10/40
SOFTWARE	FILTER software
INPUT	decoded raw data for each PRARE ground station in chronological order, clock model onboard time vs. UTC, station activity file SAF, PRARE prediction elements PRD, calibration tables range vs. AGC and Doppler,
OUTPUT	passes of corrected data in chronological order

9.2 Additional Corrections

In the second step all other corrections like

- calculation of several signal transmission path corrections (troposphere, ionosphere, center of mass distance etc),
- calculation of slant and vertical total electron content TEC, and
- calculation and definition of auxiliary informations (azimut, elevation, flags)

are carried out to generate the final Full Rate Data for each pass and observation type.

SCHEDULE	daily
HARWARE	SPARCstation 10/40
SOFTWARE	preprocessing software YVONNE
INPUT	chronological passes with corrected data due to measurement principle, clock model onboard time vs. UTC, PRARE prediction elements PRD, station activity file SAF, center of mass coordinates of ERS-2, external calibration results for range data from Potsdam SLR calibration site, external calibration results for ionospheric data correction
OUTPUT	Full Rate Data product for each pass and observation type

The output is stored on the hard disk of the SPARCstation 10/40 in a UNIX compressed form.

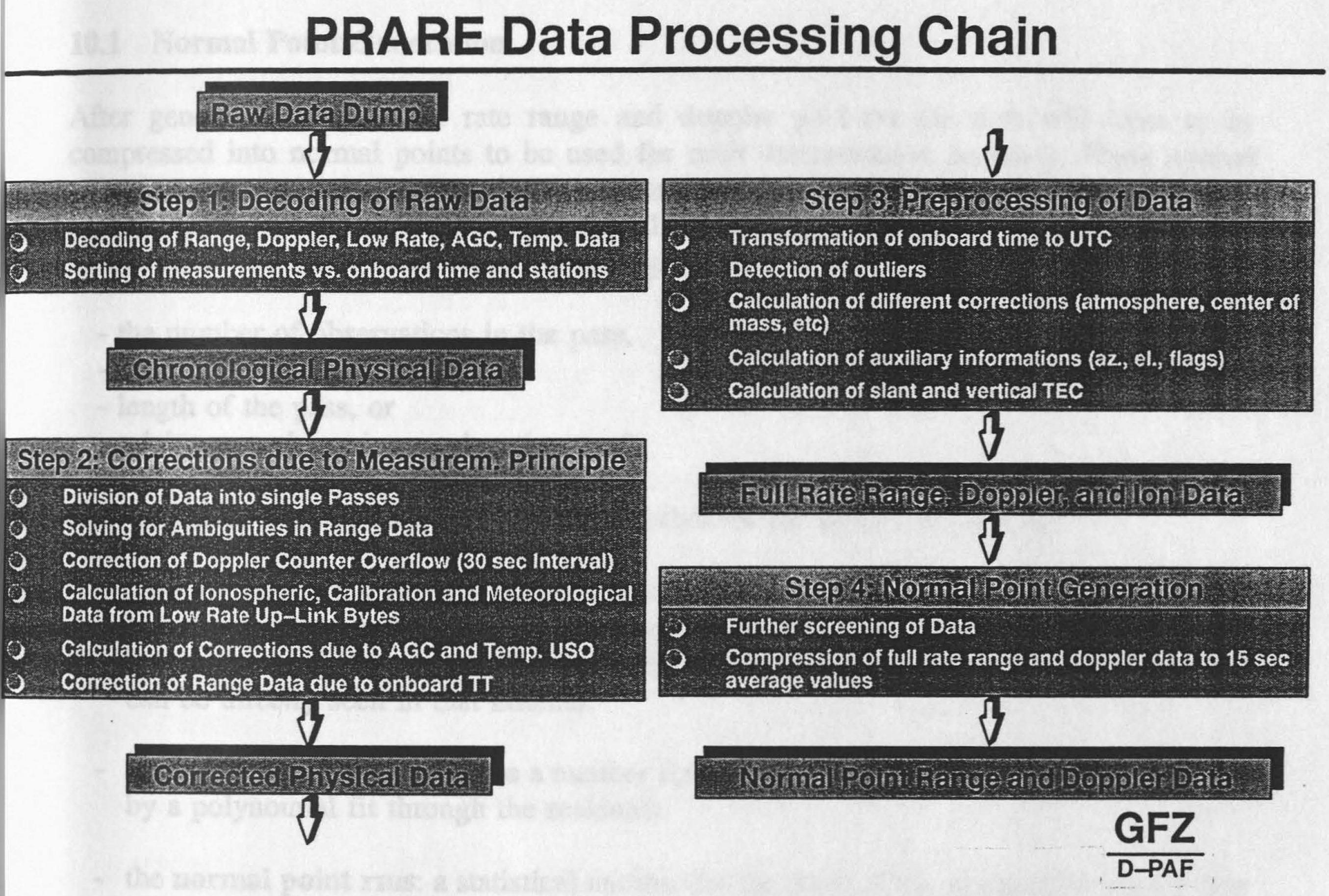

Figure 9-1: PRARE Data Processing Chain.

10 QUALITY CONTROL AND VALIDATION

10.1 Normal Point Generation

After generation of the full rate range and doppler products the data will have to be compressed into normal points to be used for orbit determination purposes. These normal points are computed for 15 sec windows according to the Herstmonceux Standards for Laser Ranges. One representative observation for all full rate data within that window is calculated. Beside some statistical information for each pass like

- the number of observations in the pass,
- start date and time,
- length of the pass, or
- minimum and maximum elevation angle

a set of values is calculated which give a number for the quality of the data:

- the **raw rms**: This value is the root mean square of all residuals within the pass. This value is very much depending on the orbit accuracy. On the other hand if this accuracy is known remaining systematic errors like station coordinate unsecurities or bias values can be directly seen in that number.
- the **poly rms**: This value gives a number for the noise of the full rate data and is derived by a polynomial fit through the residuals
- the **normal point rms**: a statistical number for the noise of the generated normal points

Beside this, the residuals are used to solve for a set of parameters like station coordinates, range and time bias (range data), or frequency offset and time bias (doppler data). The resulting normal points are stored in the PRARE directory of the SPARCstation 10/40.

SCHEDULE	daily
HARWARE	SPARCstation 10/40
SOFTWARE	normal point software PRARENP
INPUT	Range and Doppler full rate products , preliminary or predicted reference orbit, station activity file SAF
OUTPUT	Normal Point Product for each pass and observation type

10.2 External Calibration

Although the PRARE Space Segment and the Ground Stations have been calibrated before launch, and internal hardware facilities determine calibration parameters during each pass, there is still a strong requirement to monitor the overall performance of the system by comparison of the tracking data with a stable standard as it is given by data from a third generation Laser system. Such a system is permanently operated at GFZ in Potsdam.

The general idea is to compare the quasi-simultaneous PRARE and Laser measurements installed adjacent to each other at the Potsdam tracking station to derive a set of calibration parameters for the PRARE system like range and time bias values. Therefore on a routine basis all Potsdam PRARE data have to be provided to GFZ Potsdam where they will be compared with the Laser data.

For more details refer to the "PRARE In-Orbit Calibration Plan For ERS-2"

SCHEDULE	daily
HARWARE	SPARCstation 10/40
SOFTWARE	shell script "copy_data_to Potsdam"
INPUT	Potsdam PRARE products
OUTPUT	set of calibration parameters to be used in preprocessing

10.3 Calibration and Validation of the ERS-2 PRARE Ionospheric Product

The travel time delay between the two simultaneously transmitted X- and S-band signals is observed in the PRARE ground station every second and transmitted to the Space Segment as an averaged value for a 4 second interval. This observation is used during preprocessing for the ionospheric correction of the tracking data and for calculation of the total electron content (TEC) along the transmission path and in vertical direction at the Space Segment position.

To calibrate and validate the ionospheric product the following approaches are planned.

10.3.1 Calibration using Common View Technique

In reality, the two X- and S-band signals will not be transmitted at the Space Segment exactly simultaneously. There will be a constant bias instead which has to be calibrated. Additionally,

10.2 External Calibration

Although the PRARE Space Segment and the Ground Stations have been calibrated before launch, and internal hardware facilities determine calibration parameters during each pass, there is still a strong requirement to monitor the overall performance of the system by comparison of the tracking data with a stable standard as it is given by data from a third generation Laser system. Such a system is permanently operated at GFZ in Potsdam.

The general idea is to compare the quasi-simultaneous PRARE and Laser measurements installed adjacent to each other at the Potsdam tracking station to derive a set of calibration parameters for the PRARE system like range and time bias values. Therefore on a routine basis all Potsdam PRARE data have to be provided to GFZ Potsdam where they will be compared with the Laser data.

For more details refer to the "PRARE In-Orbit Calibration Plan For ERS-2".

SCHEDULE	daily
HARWARE	SPARCstation 10/40
SOFTWARE	shell script "copy_data_to_Potsdam"
INPUT	Potsdam PRARE products
OUTPUT	set of calibration parameters to be used in preprocessing

10.3 Calibration and Validation of the ERS-2 PRARE Ionospheric Product

The travel time delay between the two simultaneously transmitted X- and S-band signals is observed in the PRARE ground station every second and transmitted to the Space Segment as an averaged value for a 4 second interval. This observation is used during preprocessing for the ionospheric correction of the tracking data and for calculation of the total electron content (TEC) along the transmission path and in vertical direction at the Space Segment position.

To calibrate and validate the ionospheric product the following approaches are planned.

10.3.1 Calibration using Common View Technique

In reality, the two X- and S-band signals will not be transmitted at the Space Segment exactly simultaneously. There will be a constant bias instead which has to be calibrated. Additionally, the measurement of the travel time delay between the two received signals in the ground stations can have a systematic error which has also to be corrected. Because both errors - at the Space Segment and at the ground station - are totally correlated only the common effect can be determined.

If one uses passes which are observed by more than 1 station at the same time (common view) the requirement that all vertical TEC observed from the different stations have to be the same can be used to calculate a bias for the Space Segment or one bias for each station in a least squares adjustment.

SCHEDULE	daily
HARWARE	SPARCstation 10/40
SOFTWARE	ION_CAL
INPUT	ionospheric products from stations in common view, station activity file SAF
OUTPUT	calibration parameters to be used in preprocessing

10.3.2 Calibration using Faraday Rotation Measurements

Measurements of the ionospheric total electron content TEC can be obtained from the Faraday rotation that linear polarized radio waves from geostationary satellites suffer when crossing the ionosphere. Dependent on the electron density and on the intensity and direction of the geomagnetic field the polarization plane is rotated by the so called Faraday angle. This rotation can be used to derive the corresponding TEC along the transmission path.

One PRARE ground station will be installed in Hobart/Australia where also Faraday rotation observations will be performed during the ERS-2 mission. Therefore it will be possible to compare TEC derived by both systems if both measurements are performed at the same time. Additionally the observations have to be transformed to common sub-ionospheric points in case that the geostationary satellite and ERS-2 will be observed with different elevations.

This experiment will be performed in close cooperation with the DLR Neustrelitz. The ionospheric products from Hobart station have to be transmitted to Neustrelitz where calibration parameters will be calculated by the DLR on a quasi-routinely basis.

SCHEDULE	weekly
HARWARE	SPARCstation 10/40
SOFTWARE	shell script "copy_ion_data_hobart"
INPUT	ionospheric products from Hobart station
OUTPUT	calibration parameters to be used in preprocessing

For more details refer to the "PRARE In-Orbit Calibration Plan For ERS-2"

11 DATA ARCHIVING AND DISSEMINATION

Once the products of one complete week have been generated the following steps will have to be performed.

11.1 Archiving and Dissemination at D-PAF Oberpfaffenhofen

Every week the PRARE team receives automatically an order from the DMS (Database Management System) of the D-PAF to archive and catalogue the ESA global product ION of one specific week into the DFD archive.

A shell script has to be started which copies all data from the PRARE product directory in an uncompressed form to the archive directory and generates a file with meta informations like

- number of observations in a product,
- date and time of first and last observation,
- processing date and time, or
- release and quality flags

which will then be used by DMS to archive the ionospheric product.

Furtheron the data will be copied by DMS to the D-PAF FTP server where the ionospheric products can be accessed by the different users. If one user wishes to get a product on CDR a second shell script has to be started which informes the PGS (Product Generation System) which data have to be written to the CDR.

SCHEDULE	weekly
MACHINE	SPARCstation 10/40
SOFTWARE	shell script "copy_ion_to_archive" shell script "copy_ion_to_cdr"
INPUT	compressed PRARE ionospheric products
OUTPUT	ionospheric products available in the D-PAF archive, on the D-PAF FTP server, and on CDR

11.2 Archiving and Dissemination at GFZ Potsdam Data Center

After generation of a weekly full rate and normal point PRARE product (range, doppler and ion) a shell script has to be started which copies all products of one PRARE ground station to one file using the UNIX tar command. The same shell script copies this file to a SPARCstation at the GFZ in Potsdam where an automatic procedure generates meta files similar as described in chapter 11.1, copies all data to the GFZ UNITREE archive and to the GFZ FTP server, where all products can be accessed by the different ground station owners.

SCHEDULE	weekly
MACHINE	SPARCstation 10/40, CONVEX at GFZ Potsdam
SOFTWARE	shell script "copy_data_to_potsdam"
INPUT	compressed PRARE products
OUTPUT	PRARE products available in the GFZ archive, on the GFZ FTP server, and on an external medium (tbd)

12 REPORTING

GFZ will report to DARA, ESA and other institutions involved in the PRARE operations (Stuttgart Monitor Station, Dornier, ground station owners) on a weekly basis about

- PRARE Ground Station Network,
- Master Station Operation,
- Data Acquisition,
- Data Analysis,
- PRARE Prediction Accuracy, and
- Data Delivery.

Zentralbibliothek 000190097
GFZ Potsdam B 103