```
PDS_VERSION_ID      = PDS3
RECORD_TYPE         = FIXED_LENGTH
RECORD_BYTES        = 80
OBJECT              = TEXT
  PUBLICATION_DATE    = 1985-06-01
  NOTE                = "DSN Media Calibration Data File Software
                        Interface Specification.  Typed in from hard
                        copy original "
END_OBJECT          = TEXT
END
```

DOCUMENT 820-13; REV. A
DSN SYSTEM REQUIREMENTS
DETAILED INTERFACE DESIGN

TRK-2-23
DSN Tracking System Interfaces
Media Calibration Data Interface

(Insert this module in Document 820-13; Rev. A)

EFFECTIVE DATE: Mark IVA Implementation

Initial Release Date: June 1, 1985

Approved by: s/Joseph A. Wackley (430)

s/Herbert N. Royden (335)

s/Gene L. Goltz (314)

A. PURPOSE

This module defines the formats and content of the media calibration data provided by the Tracking System Analytic Calibration (TSAC) group.

B. REVISION AND CONTROL

Revisions or changes to the information herein presented may be initiated in accordance with the procedures in Section I of this document.

C. GENERAL INFORMATION

Media calibrations provided by the DSN are used by project navigation teams to improve the accuracy of spacecraft orbit determination; they are also used by project Radio Science teams and other investigators. The calibrations comprise corrections for the effects of transmission media (troposphere, ionosphere, and solar plasma) on the radio metric data. The media calibrations are to be provided at intervals determined by the accuracy and timeliness requirements of the primary users and by negotiations with the various DSN users.

D. DATA FORMATS

1. General Description

All TSAC calibrations are provided in the form of card images (or punched cards, if necessary) in files on the JPL user's computer. On the Univac 1100/81 computers, the files are in field data format (SDF); on all other computers, they are in American Standard Code for Information Interchange (ASCII) format.

TSAC media calibrations conform to the Command Statement Processor (CSP) English-like command language used by the Orbit Determination Program (ODP) to adjust, delete, or weight data points. The language is

described in detail in the DPTRAJ-ODP User's Reference Manual (618-783 Rev. B, Vol. 1, Section 36).

In general, a CSP command consists of a verb and optional scope limiters and computation specifiers, terminated by a period. A command may, and frequently does, extend over more than one card image. The CSP commands produced by the TSAC software comprise a small subset of those used by the ODP. Elements of CSP commands used in the TSAC media calibrations are given in Table TRK-2-23-2; examples of the calibrations are given below under the sub-headings Tropospheric Calibrations, Ionospheric Calibrations, and Solar Plasma Calibrations.

Table TRK-2-23-1. CSP Elements Used in TSAC Media Calibrations

Type of Element	Elements Used
Verbs	ADJUST, DELETE
Scope Limiters	Time Span Limiters: FROM BEFORE TO AFTER AT Network (Complex or Station): DSN C10 11, 12, 13, 14 C40 42, 43, 44 C60 61, 62, 63 Band: S, X; L (VAX ODP only) Source: SCID, QUASAR
Computation Specifiers	Series Type: BY NRMPOW BY DNRMPOW BY CONST BY DCONST BY TRIG BY DTRIG Model: DRY NUPART (dry troposphere) WET NUPART (tropospheric water vapor) CHPART (ionosphere) DRVID (ionosphere + solar plasma) Data Type: DOPPLER F1, F2, F3, F3C RANGE PLOP VLBI DVLBI

2. Time Formats

Times are preceded by a time-span limiter (FROM, TO, AT, BEFORE, or AFTER) and are enclosed in parentheses. The format is (YY/MM/DD,HH:MM:SS). The year, month, day, hour, and minute values are integers; seconds are double precision. Up to three of the right-most time fields may be omitted. When omitted, their values are taken to be zeroes. The calibrations apply only during the times specified by the time-span limiter(s). If the limiter is AT, the time span depends on the computer word length. On the UNIVAC (36-bit word length), the time span is from one microsecond before the given time to one microsecond after; on the VAX

(32-bit word length), it is from one millisecond before to one millisecond after.

3. Number Formats

The formats for integers and single- and double-precision floating-point numbers are the same as in FORTRAN. In addition, the sign of the exponent of a floating point number may replace the letter D or E; for example, 1.234E-3 may be written 1.234-3.

4. Comments

Additional explanatory information, not to be used by the ODP, may appear on a command provided that it is preceded by the number sign (#). Characters following the number sign are ignored by the ODP.

5. Series Type

Media calibrations may be specified by a normalized power series (NRMPOW), a single constant (CONST), or a Fourier series (TRIG). If the coefficients or constant are double precision, the computation specifier is preceded by the letter "D" (e.g., DNRMPOW).

If the ADJUST command contained BY NRMPOW (C0, C1, ..., CN) FROM (S) TO (E), where S and E refer to the start and end times for the command, the calibration is computed from the normalized power series C0 + C1 * X + C2 * X^2 + ... + CN * X^N. This polynomial is called "normalized" because the time argument of the series, T, has been replaced by the normalized, dimensionless argument X, which is defined to be -1 when T = S and +1 when T = E. This normalization is done by a change of variable given by

$$X = 2*((T-S)/(E-S)) -1.$$

Up to 24 single-precision or 12 double-precision coefficients are allowed in one series.

If the ADJUST command contains BY CONST (C), the calibration is given by the constant C.

If the ADJUST command contains BY TRIG (P, A0, A1, B1, A2, B2, ..., AN, BN) AFTER (S), the calibration is given by the Fourier series

$$A0 + A1 \cos x + B1 \sin x + A2 \cos 2x + B2 \sin 2x + \ldots + AN \cos Nx + BN \sin Nx,$$

where x = 2 * PI * (T-S)/P; P is the period of the fundamental mode, in seconds.

6. Sign of Calibration

In the ODP, the calibration is, effectively, always subtracted from the observable. Range calibrations, then, will always be positive; a positive sign corresponds to a range delay.

7. Tropospheric Calibrations

Tropospheric calibrations are currently given by a normalized power series representing the seasonal variation over a two-year span. Two series are given for each station or complex; the "dry" and "wet" components of one-way zenith range delay in meters. The dry component, typically about 2 meters, is the delay due to the nonwater-vapor components of the atmosphere (N2, O2, CO2, and Ar), whose proportions are essentially constant. The wet component, typically a few centimeters, is the contribution of the highly variable water-vapor content of the atmosphere. The program using the tropospheric calibrations must determine the line-of-sight delay by mapping each zenith component to the elevation angle corresponding to the line-of-sight; the ODP performs this function by using separate dry and wet mapping tables.

An example of the format for tropospheric calibrations is given in Figure TRK-2-23-1 of this module.

```
|=========================================================================|
|ADJUST (ALL) BY NRMPOW (.5385215940876400-001,-.1545263252791661+000,    |
| .6120410421392178+000,.8393903860788785+000,-.1757061589993537+001,     |
| -.1192449606993796+001,.1774783212089319+001,.6265889342013949+000,     |
| -.7481685636314813+000,-.1116904190364361+000,.1136781820255777+000) MODEL|
| (WET NUPART) FROM (83/1/1,00:00:00.01) TO (85/1/1) DSN (C10).           |
|=========================================================================|
```

Figure TRK-2-23-1. Format for Tropospheric Calibrations

8. Ionospheric Calibrations

Ionospheric calibrations are given by a normalized power series for each spacecraft pass at each DSN complex. The calibration represents the one-way line-of-sight ionospheric range delay in meters at S-band (2295 MHz). >From this polynomial, the ODP calculates Doppler corrections (in Hz) and range corrections (in range units) for each data point in its OD file.

The magnitude of the vertical ionospheric range delay at each complex depends on time of day, season, and time since start of the current solar cycle; it can range from less than 1 meter to more than 8 meters. Because the slant-range adjustment factor can vary from unity at zenith to about 3.5 at 0 degrees elevation, the resulting total variation in line-of-sight ionospheric calibration can range from less than 1 meter to more than 25 meters.

The time spans of each polynomial, except in special circumstances, are from spacecraft rise (0 deg) to spacecraft set (0 deg) at the station or complex.

An example of the format for ionospheric calibrations is given in Figure TRK-2-23-2.

```
|=========================================================================|
|ADJUST (ALL) BY NRMPOW (.127504448000000D+001,-.363046489000000D+000,    |
| .221433675000000D+001,.385002747000000D+000,-.476505244000000D-001,     |
| -.379998393000000D+000) MODEL (CHPART) FROM (84/10/31.20:40:55) TO       |
| (84/11/1,10:45:30) DSN (C40). #S/C32 PRED S66 841011                    |
|=========================================================================|
```

Figure TRK-2-23-2. Format for Ionospheric Calibrations

9. Solar Plasma Calibrations

Solar plasma calibrations are given by a single constant that applies only at the time tag of an individual data point. Units are the same as those of the observables; for example, range units for range and Hertz for Doppler. The TSAC software reads the ODP input data file to get the time tags, and also removes the ionospheric portion of the downlink S/Z dual-frequency Doppler measurements so that only the solar plasma contributions remain.

An example of the format for solar plasma calibrations is given in Figure TRK-2-23-3.

```
|=========================================================================|
|ADJUST (F2) BY CONST (.38755-001) AT (84/10/1.00:03:30) DSN (43) BAND (S). |
|ADJUST(PLOP) BY CONST (.69398+002) AT (84/10/1.00:19:46) DSN (43) BAND (S).|
|ADJUST (F2) BY CONST (.36505-001) AT (84/10/1.00:20:30) DSN (43) BAND (S). |
|ADJUST (F2) BY CONST (.20189-001) AT (84/10/1.00:36:30) DSN (43) BAND (S). |
|ADJUST(PLOP) BY CONST (.54675+002) AT (84/10/1.00:38:03) DSN (43) BAND (S).|
|ADJUST (F2) BY CONST (-.58993-001) AT (84/10/1.00:47:30) DSN (43) BAND (S).|
|ADJUST (F2) BY CONST (-.50877-001) AT (84/10/1.00:54:30) DSN (43) BAND (S).|
|ADJUST(PLOP) BY CONST (.69124+002) AT (84/10/1.00:56:20) DSN (43) BAND (S).|
|ADJUST (F2) BY CONST (-.70260-001) AT (84/10/1.01:01:30) DSN (43) BAND (S).|
```

|===|

Figure TRK-2-23-3. Format for Solar Plasma Calibrations

NB: First number in parentheses has been truncated from 10 mantissa digits to 5 mantissa digits to permit display within 80 character line limit here.