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Computation and Application of the **TOPEX/POSEIDON Orbit Event File**

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During the TOPEX/POSEIDON mission design process, the need was identified for software capable of generating a predicted set of orbital events for use in view period scheduling and sequence planning. As a result, the Mission Design Section of the Jet Propulsion Laboratory developed the Orbit Event Program (OEP) as an extension of the Planetary Observer Planning Software (POPS). The OEP is an analytical software tool that searches for the occurrence of various satellite geometries relative to the earth, sun, Deep Space Network (DSN) stations, and the Tracking and Data Relay Satellite System (TDRSS). in general, the events computed by the OEP are functions of the spacecraft trajectory and attitude.

The OEP is used by the TOPEX/POSEIDON Navigation Team (NAVT) to generate an Orbit Event File (OEF), which consists of a select group of time-orderd events to be used in mission planning for the TOPEX/POSEIDON spacecraft, These events include orbit revolution occurrences, land/sea crossings, verification site closest approach, DSN station rises and sets, TDRSS rises and sets, spacecraft occultation from the sun, solar interference with communication links, orbit sun time, beta-prime (β' is defined as the angle between the earth-sun vector and the projection of this vector onto the orbital plane) events, and Radio Frequency Interference (RFI) and South Atlantic Anomaly (SAA) zone entry and exit. Events related to the TOPEX/POSEIDON High Gain Antenna orientation and gimbal angle rates are also included. For each event, the day number and time of the event, cycle number, pass number, rev number, latitude, longitude, event mnemonic, and event identification number are written to the OEF. Table 1 is an example of an abbreviated OEF, containing TDRSS view period information and verification site overflight occurrences, in addition to the OEF, a variety of orbital parameters (IWANTS) can be written to an ASCII file upon the occurrence of specific orbit events, or at user-defined time steps.

A thirty second accuracy requirement was placed on the OEP by the TOPEX/POSEIDON Ground system. More specifically, it is required that each event time printed to the OEF be accurate to within thirty seconds of the actual orbital event experienced by the. spacecraft, A variety of methods have been employed to test individual print events in the OEP, including a rigorous comparison with a Predicted Site Acquisition Table (PSAT) supplied by NASA Goddard Space Flight Center (GSFC). Ongoing experience has motivated refinements in the models employed by the OEP, to increase accuracy in the computation of orbital events. Flight data received in the telemetry during TOPEX/POSEIDON operations has verified the accuracy of the events written to the OEF. For example, Table 2. contains data associated with solar occultations experienced by TOPEX/POSEIDON. Flight data received from the on-bead coarse sun sensor is compared with the occultation times as predicted by the OEP. Originally, the height of the atmosphere used by OEP for occultation computations was 90 km. Following the comparison with actual flight data, the atmosphere height input for the OEP was decreased to 27 km.

The spacecraft ephemeris processed by the OEP is created by the Planetary Observer Long-Term Orbit Predictor (POLOP). The POLOP software, included in the original POPS package, integrates an initial set of classical mean orbital elements in a nonrotating planet mean equator and equinox of epoch coordinate frame. Forces modeled by POLOP can include gravity spherical harmonics, atmospheric drag, solar radiation pressure, and luni-solar third body effects.

During mission operations, the GSFC Flight Dynamics Facility (FDF) provides the Jet Propulsion Laboratory TOPEX/POSEIDON Navigation Team with orbit determination solutions based on tracking data, in the form of Extended Precision Vectors (EPVs). The EPVs are transmitted via NASCOM through the Telemetry, Command and Communications Subsystem (TCCS) from the FDF to the NAVT, as shown in Figure 1. The Navigation Team converts the vectors into mean elements for use in orbit propagation. The Satellite Performance Analysis Team (SPAT) provides constraints related to the satellite geometry for input into the OEP. The resulting OEF is then delivered by the NAVT to the Mission Planning and Sequencing Team (MPST) for use in developing the mission sequence.

Prior to launch, the OEP was used extensively in the design of the TOPEX/POSEIDON operational orbit and the. assessment phase maneuver sequence. During routine TOPEX/POSEIDON operations, the OEF is delivered to the MPST on a weekly basis. A standard OEF covers a fourteen day time period, beginning at 00:00:00 GMT on the fourth Monday following each Wednesday EPV delivery.

From the OEF, the Mission Planners generate several products. The events of the OEF arc incorporated into the Sequence of Events (SOE) and the Space Flight Operations Schedule (SFOS). The SOE is a listing of the stored and real-time commands to be uplinked to the satellite, while the SFOS is a timeline of TOPEX/POSEIDON activities in graphical form. The OEF is also used as input for the TDRSS Resource User's Scheduling TOOL software., developed by the University of Colorado for scheduling TDRSS and DSN activities. A sample OEF Views Chart, as produced by the MPST, is shown in Figure 2.. The Views Chart displays available view periods for two selected TDRSS satellites and the Deep Space Network stations. The MPST also uses the land/sea crossing information provided in the OEF to determine appropriate times to enact special procedures, such as altimeter boresight calibration maneuvers.

The OEP has proven to be a versatile piece of mission operations software with a wide range of applications. The program may be useful for planetary orbiters other than TOPEX/POSEIDON. Only the events related to the, High Gain Antenna field of view arc specific to the TOPEX/POSEIDON mission; the remainder of the events may applicable to other missions, including those designed to orbit bodies other than earth.

Table 1. Sample Orbit Event File.

```
* TYPE: OEF
* FILENAME= NAV_OEF1 . TXT7
* BEGIN= 1993-031T14:45: 00.000
* END= 1993- 031T17 :25:00. 000
* TEAM= NAVT
* OPER= AHMED SALAMA -- EXTENSION 3-0983
* PROJ= TOPEX/POSEIDON
* PROG= OEP Version 3.6 - 26 Aug 1992
* SIS ID: 633-743-23-005
*
* USER IN PUTS
*  31= SITE1
*      NAM= NASAVERF
*             SITE1= 239,319,   34.469,    0.000
*      ELVMSK( 4)=    0.000
*      RNADIR( 4)=   30.000
* 210= TDEEZSET
* 211 = TDEEZRI S
* 220= TDESPSET
* 221 = TDESPRI S
*      TAR= TDRSE
*      LAT=    0.00
*      WLO=   41.00
*      ALT= 35786.029
* 230= TDWEZSET
* 231= TDWEZRI S
* 240= TDWSPSET
* 241= TDWSPRIS
*      TAR= TDRSW
*      LAT=   0,00
*      WLO= 1'/4.00
*      ALT= 35786.029
* 250 = TDEHGSET
* 251= TDEHGRIS
*         RATEA=  30 . 00
*         RATEB=  30 .00
*         HGABL =  80.00     88.00
*      1 HGADIV=     12        12         12
*      TAR= TDRSE
* 260= TDWHGSET
* 261= TDWHGRIS
*         RATEA=  30.00
*         RATEB=  30.00
*         HGABL =  80.00     88,00
*      IHGADIV=      12        12         12
*      TAR= TDRSW
* 2'/1 = TDECORI S
* 270= TDECOSET
*      SCAMSK(13)= -33,00
*      TAR= TDRS E
* 281= TDWCORI S
* 280= TDWCOSET
*      SCAMS:   -33.00
*      TAR= TDRSW
*
*NO       EVENT TIME         CYC PAS   REV   LON     LAT   MNEMONIC
*.............  ....        ..   ----  ------         ......
271 1993- 031T14 45:15.745   14  40   2224 152.61 -65.07 TDECORIS
211 1993- 031T15 03:13.423  14  41   2224 237.31 -36.16 TDEEZRIS
240 1993-031T15 30:24.316  14  41   2225 272.83  42.10 TDWSPSET
241 1993-031T15 33:06.879  14  41   2225 279.36  49.16 TDWSPRIS
230 1993-031T15 33:06.879  14  41   2225 279.36  49.16 TDWEZSET
280 1993- 0311'15 46:07.292  14  42   2225 352.93  65.13 TDWCOSET
250 1993-031T15:53:27.361  14  42   2225  29.25  5] , 85 TDEHGSET
210 1993- 031T15 :55:01.440 14  42   2225  33."/6  4 '/ .9:> TDEEZSET
251 1993- 031T15:55:08.661 14  42   2225  34 .0'/  4-1.64 TDEHGRIS
281 1993-031T16:20:46.874  14  42  2225  68.94 -25.81 TDWCORIS
231 1993- 031T16:30:50.605  14  42  2225  89.76 -52.87 TDWEZRIS
211 1993- 031T17:14:45.412 14  43  2226 231.91  19.34 TDEEZRI S
 31 1993-031T17:20:03.261  14  43  2226 239.31  34.4"/ SITE1
```

Table 2. Coarse Sun Sensor Flight Data Compared with OEP Occultation Predictions

CSS Flight Data UTC Start-Stop Times 1993 DOY hour:min:sec	OEP Predictions (27 km atmosphere height) UTC Start-Stop Times 1993 DOY hour:min:sec	OEP Predictions (90 km atmosphere height) UTC Start-Stop Times 1993 DOY hour:min:sec
013 16:50:36 - 17:24:44	013 16:50:28 - 17:24:45	013 16:50:12 - 17:25:07
013 18:43:06 - 19:17:14	013 18:47:57 - 19:17:12	013 18:42:40 - 19:17:28
013 20:35:36 - 21:09:36	013 20:35:25 - 21:09:39	013 20:35:08 - 21:09:55
013 22:27:58 - 23:02:06	013 22:27:53 - 23:02:06	013 22:27:37 - 23:02:22
014 00:20:29 - 00:54:37	014 00:20:21 - 00:54:33	014 00:20:05 - 00:54:49
014 02:12:59 - 02:46:59	014 02:12:50 - 02:46:59	014 02:12:33 - 02:47:16
014 04:05:29 - 04:39:29	014 04:05:18 - 04:39:26	014 04:05:01 - 04:39:43
014 05:57:51 - 06:31:51	014 05:57:46 - 06:31:53	014 05:57:30 - 06:32:10
014 07:50:21 - 08:24:21	014 07:50:14 - 08:24:20	014 07:49:58 - 08:24:37
014 09:42:51 - 10:16:51	014 09:42:43 - 10:16:47	014 09:42:26 - 10:17:03

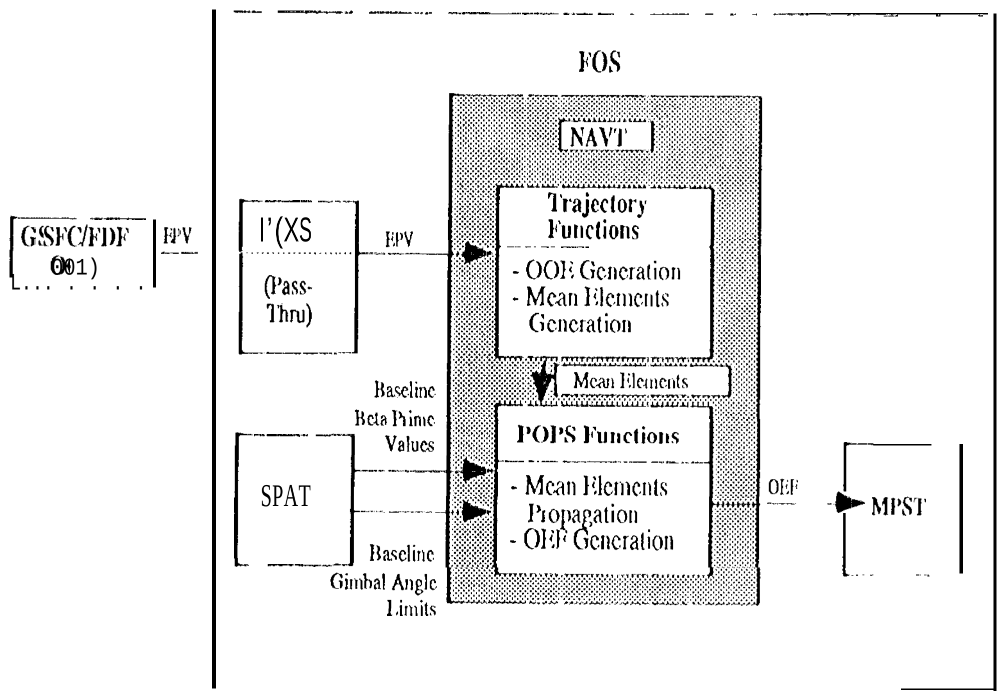

Figure 1. OEF Data Flow Block Diagram.

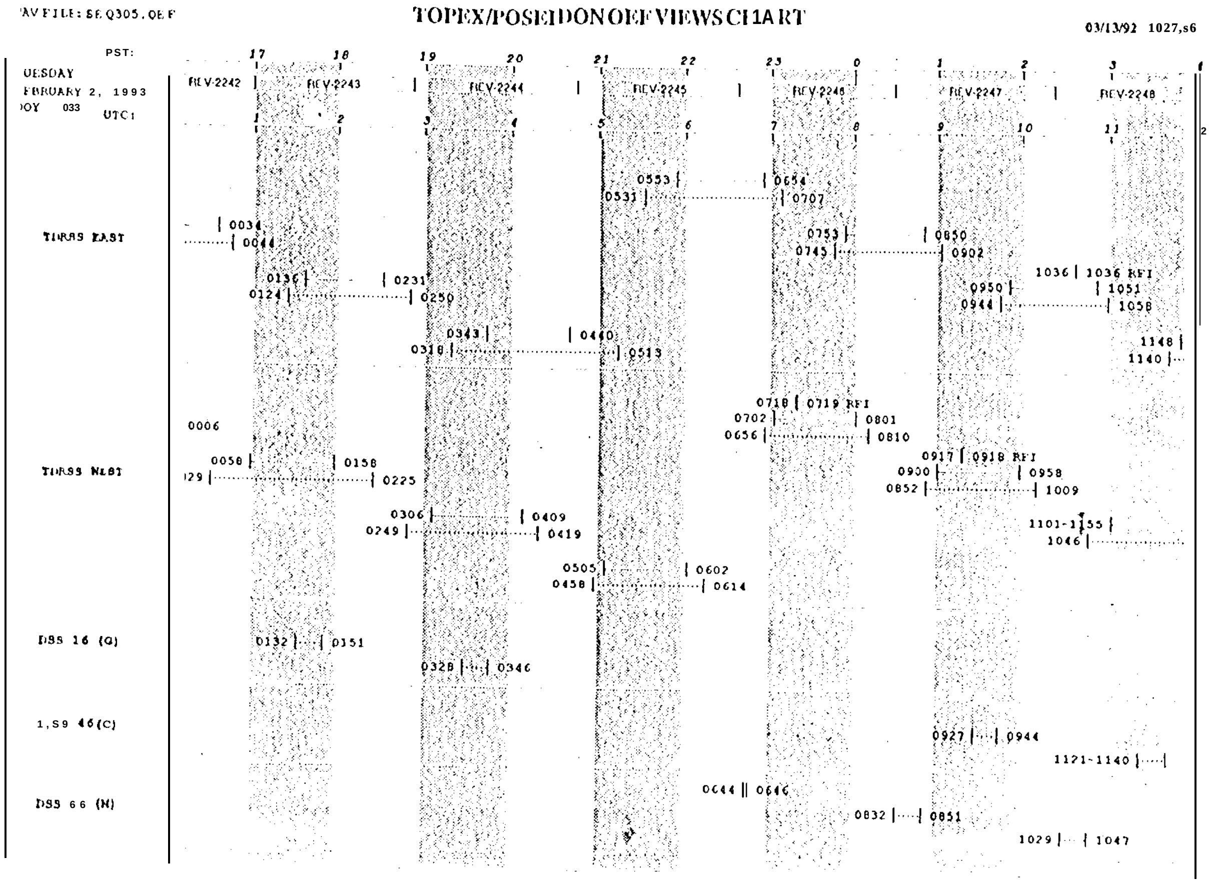

Figure 2. OEF Views Chart.