DATA ON TIME AND POLAR MOTION: IMMEDIATE ACCESSIBILITY

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ABSTRACT

Users of time and polar motion information have requirements for data which are somewhat different from those usually considered for astronomical data files. Because of these requirements, it is necessary to provide immediate access to the latest information on Earth orientation and even predictions of future orientation. For other applications where data of the highest accuracy is required with little concern for the delay between observations and the determination of the required information, a more traditional approach may be used. To meet all of these needs a versatile automated data retrieval system is demanded. The U. S. Naval Observatory is now implementing such a system in the area of Earth orientation information and for precise time and time interval applications. Data are available through a series of weekly, monthly, and annual reports, as well as through a digital communications link to Time Service machine-readable files.

INTRODUCTION

The U. S. Naval Observatory provides, as part of its mission, data necessary for accurate navigation on Earth and in space. In this context, time, both atomic and astronomical, and polar motion information are essential. Astronomical time (UT1) and polar motion may be considered as angles which are required to specify completely the orientation of the Earth in a quasi-inertial reference system (Kovalevsky and Mueller, 1981). Astronomical time is a measure of the rotation angle of the Earth while polar motion refers to the changing position of the rotational pole with respect to the Conventional International Origin (CIO) as defined by adopted station coordinates and models. Atomic time defined by the frequency of an energy level transition in the cesium atom serves as a basis for civil time and provides a uniform time scale for practical applications.

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Earth orientation information and intercomparison of time scales may be obtained only through observations. In the case of Earth orientation, observations are made to derive the necessary angles. Time and frequency measurements are made to determine accurate time scale data. The information derived from these observations and measurements must be provided to users in a manner suitable to meet their needs.

DATA CONSIDERATIONS

The usefulness of data available to the user may be characterized by a number of parameters. Among these are precision, accuracy, consistency, resolution, and availability. By precision we refer to the formal mean error of the determination as derived from the observations made during one observing session. External precision measures the variations from session to session, and is numerically estimated using the residuals from a smooth curve or the Allan Variance. Precision is measured with respect to an internal reference system. Accuracy, however, incorporates the concept of a "standard" reference system, and is used to characterize the agreement of the derived data with a standard data set. Numerically this may be estimated using the rms of the residuals with respect to a standard data set.

In general, systematic errors may exist in the derived data, and if these can be accurately estimated it is possible to refer the data to the standard reference system. Consistency refers to the stability of the systematic errors in time. A highly consistent system is one in which the systematic errors do not change over extended periods of time. Resolution in this context refers to how often independent estimates of the derived data are available. High resolution implies a rather short observing session in order to obtain useful data. Availability refers to the time interval between the end of the observing session and the time when the derived data are available. Those making use of the derived data must evaluate their needs in terms of these quantities to determine the usefulness of various possible sets for their particular applications. For example, high accuracy may have to be compromised in favor of high resolution or immediate availability.

USER REQUIREMENTS

Ideally, it would be desirable to have high accuracy data with the highest resolution available almost immediately after observing. Realistically, compromises must be made. Thus it seems appropriate that requirements for time and polar motion information may be classified into three categories.

"Historical" data of the highest possible accuracy and consistency are needed by those engaged in scientific research and for geodetic purposes. While it may be desirable to have the data as soon as possible, users of historical data may not be concerned with immediate availability if it is only possible at the expense of reduced accuracy or consistency.

"Current" data are required by users needing high precision and almost immediate availability. They are willing to sacrifice the consistency and accuracy of the data to some extent in order to meet their need for the most current information available. Those involved with navigation frequently fit into this area.

"Future" data are required for those applications where predictions are required. For example, if predictions of some phenomenon are demanded in which time and polar motion play a part, these users must have projected values with the highest possible precision and consistency.

These three types of user requirements, in turn, demand a versatile system for data retrieval. For the user of historical data, reports issued annually may be sufficient. Clearly this would not be useful to those who need predictions of time and polar motion updated on an immediate basis.

AVAILABLE DATA

Time and polar motion information are currently available from a number of sources including international services. The International Latitude Service (ILS) organized in 1899 has provided polar coordinates since that time. These have been obtained using the observations of five visual zenith telescopes located on the parallel of 39° N. While these locations have served as the definition of the CIO, the accuracy of the data derived from these observations has been superseded by the use of more modern techniques and methods. ILS data are available generally after a processing delay of a few months.

Since 1962, the International Polar Motion Service (IPMS) has provided polar coordinates derived from observations made with approximately sixty classical astronomical instruments located around the world. These data are available some months after the actual observations.

The Bureau International de l'Heure (BIH) provides time information as well as polar coordinates. Both astronomical and atomic time are coordinated through this international service. The polar coordinates are determined making use of information from the Doppler tracking of artificial satellites as well as the results from a large number of classical astronomical instruments. The data are generally available one to two months after the observations.

The BIH also maintains a Rapid Service which provides Earth orientation information based on the observations of a subset of the previously mentioned classical instruments. The data are available from one to ten days following observations at an accuracy somewhat lower than that associated with the regular BIH data.

In addition to these data sets, a number of independent data sets are available containing data from various observatories. For example,

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the U. S. Naval Observatory has a continuous record of the of variation of astronomical latitude at Washington since 1915 and UT1-UTC since 1955. These data are based on observations made with a photographic zenith tube. Similar information is available from other observatories, including the Royal Greenwich Observatory, Paris, Hamburg, Ottawa, and Tokyo. Polar coordinates derived from the tracking of Doppler navigational satellites are also available from the U. S. Defense Mapping Agency starting in the late 1960's. Recently, modern techniques such as laser ranging to artificial Earth satellites and to the Moon, and radio interferometry, have provided additional sets based on completely different observational methods. Possible systematic errors involved in each of these methods remain to be investigated, but these observations show a new promise for increased accuracy and consistency.

For predictions of future Earth orientation parameters, the U. S. Naval Observatory also provides routine weekly updated predictions of astronomical data. They are available through weekly publications and by means of a digital communications link. This latter service (see Time Service Announcement Series 14, No. 27. 1980) provides the latest information available in the area of precise time and time interval as well as the predictions of Earth orientation.

SUMMARY OF U. S. NAVAL OBSERVATORY TIME SERVICE DATA

Appendix A lists the Time Service Publications currently available on a weekly, monthly or annual basis. As mentioned above, a digital communications link is also available for immediate automatic retrieval of data. Among some of the data files available through this service are the notes of the most recent Series 4 publication (see Appendix A). up to the last ten Series 5 messages, predictions of polar coordinates and UT1, and preliminary values of the difference between the Master Clock and UTC(USNO). Also included in the approximately forty files available are general messages of interest to the user as well as information on the status of OMEGA, Loran-C, and GPS. The most recent monitoring information from GPS, OMEGA, Loran-C, TRANSIT, and television timing is also available. A time signal is provided which can be used to set a computer on time if the communications link is called by the user's computer and an appropriate program to set the system clock is available. The precision is currently limited to ± 10 milli—seconds. The data of all these files and time signal are available immediately to the user with a suitable computer terminal. Thus the digital communications link is designed to meet the needs of those users for immediate information. Appendix B contains a partial explanation of the use of the communications link. Further information can be obtained by writing to: Director, Time Service Division. U. S. Naval Observatory. Washington, D. C. 20390 U.S.A.

FUTURE PLANS OF THE U. S. NAVAL OBSERVATORY

To meet user requirements the U. S. Naval Observatory is currently implementing a system of astronomical time and polar motion data based on the use of classical observations as well as the results available from the modern techniques (McCarthy. 1981). The latter methods include laser ranging to the Moon and to artificial satellites and the connected element interferometer at Green Bank. Predictions of future Earth rotation parameters will be based on this set of data. It is expected that all data types (historical, current, and future) will be available to the user immediately in machine-readable form through the digital communications link. The user will need to specify only the date(s) for which the information is required and the data will be retrieved along with the corresponding estimates of precision.

Already existing files dealing with precise time and time interval information will be expanded as needed to suit user requirements. For example, it is expected that the current limitation in precision of the time signal provided by the digital communications link will soon be improved to meet user needs.

CONCLUSION

As future requirements for time and polar motion information become more stringent both in terms of accuracy and availability it will become more important to assure that data files can be retrieved immediately by users. The U. S. Naval Observatory is already providing such a system for users of precise time and time interval information as well as those requiring predictions of Earth orientation. It is planned that this system will be expanded to meet already existing demands as well as future requirements.

APPENDIX A. LIST OF U. S. NAVAL OBSERVATORY TIME SERVICE PUBLICATIONS

Series 1 WORLDWIDE PRIMARY TIME and FREQUENCY VLF and HF TRANSMISSIONS. Includes call sign, geographic location, frequencies, radiated power, times of broadcast, etc., of radio transmissions suitable for precise time measurement. Contains sections pertaining to U. S. Navy time and frequency transmissions, Loran-C, OMEGA, National Bureau of Standards (NBS) and other time signals. (Issued as necessary.)

Series 4 DAILY PHASE VALUES and TIME DIFFERENCES. Lists observed phase and/or time difference between VLF, LF, OMEGA, television, portable clock measurements, Loran-C stations and the U. S. Naval Observatory (USNO) master clock, UTC(USNO.MC). Propagation disturbances and notices of interest for precision timekeeping are also given. (Issued weekly.)

Series 5 USNO PHASE VALUES/TELETYPE MESSAGE. Lists information described in Series 4 as it becomes available. TWX message for U. S. Government addresses only after submission of written justification to the Superintendent.

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Series 6 A.1 - UT1 DATA. Lists daily values of polar coordinates, correction for seasonal variation, and A.1-UT1 as observed at USNO and Naval Observatory Time Service Substation (NOTSS), Richmond, Florida. The astronomical latitude as observed at each station is also given. (Issued monthly.)

Series 7 PRELIMINARY TIMES and COORDINATES of the POLE. Lists general time scale information, values of UT1-UTC predicted two weeks in advance, the Bureau International de l'Heure (BIH) values of UT1-UTC and polar coordinates. Doppler Polar Motion Service, IPMS and ILS polar coordinates are also listed as they become available. (Issued weekly.)

Series 8 TIMES of COINCIDENCE (NULL) EPHEMERIS TABLES for TELEVISION. At present these tables are applicable only for WTTG Washington, D. C. and KTTV Los Angeles, CA. They may be of interest in countries operating on the NTSC system. (Issued annually).

Series 9 GENERAL INFORMATION for LORAN-C. Individual tables are issued for the master station of each Loran-C chain. (Issued annually.)

Series 10 ASTRONOMICAL PROGRAMS. Includes information pertaining to results, catalogs, papers, etc., concerning the Photographic Zenith Tube (PZT), Danjon Astrolabe, and Dual-Rate Moon Position Camera. (Issued as available.)

Frequently this information will be released as a Time Service Announcement Series 14.

Series 11 TIME SERVICE REPORT. List general timing information and time differences between coordinated stations and the UTC time system; adopted differences UT1-UTC and A.1-UT1; UTC(USNO MEAN)-UTC(USNO MC); UTC(USNO MC)-UTC(BIH); astronomical latitude and UT1 as observed at USNO and NOTSS; polar coordinates and corrections for seasonal and polar (longitude) variations. (Issued annually.)

Series 13 PRECISE TIME and TIME INTERVAL PLANNING MEETING. Includes announcement of the meeting held each December in Washington, D. C., the call for papers, and the preliminary program.

Series 14 TIME SERVICE ANNOUNCEMENTS. Includes general information pertaining to time determination, measurement, and dissemination. (Issued as required.)

Series 15 BUREAU INTERNATIONAL de l'HEURE CIRCULAR D. Lists Universal Time and coordinates of the pole; emission time of time signals; Universal Time (Coordinated) from Loran-C and television pulse receptions and independent local atomic time scales (AT_i). This publication is distributed to U. S. addresses only. (Issued monthly.)

Series 16 PRECISE TIME TRANSFER REPORT. Lists the time difference UTC(USNO MC)-UTC (reference clock), adjustments to reference clocks and portable clock measurements. The time difference is obtained via communication satellite time transfer, television and/or Loran-C receptions. (Issued each 20 days.)

Series 17 TRANSIT SATELLITE REPORT. Lists the difference UTC (satellite clock) - UTC (USNO MC) and the frequency offset for each of the operational satellites. The information published is received from Naval Astronautics Group, Pt. Mugu, CA. (Issued weekly.)

Series 18 WORLD DATA CENTER-A, ROTATION of the EARTH, INFORMATION BULLETIN. Lists proposed times for experiments utilizing modern techniques, such as radio interferometry and laser ranging. When available, preliminary values for polar motion and Universal time obtained from these techniques are given. (Issued as available.)

NOTES:
(1) Past issues of Series 4 are available on microfiche.
(2) Series 6 is available in machine-readable form at the usual exchange ratio of three-to-one.

APPENDIX B. EXPLANATIONS FOR USE OF THE USNO REMOTE DATA ACCESS SYSTEM

You have available a number of info services which can be called by sending a key sequence as given in Table of Codes, terminated by CR. Example: To get Table of Codes type in @TCO (and carriage return).

Use full duplex, 300 or 1200 BAUD, even parity, ASCII seven level, 10 bits per character with start, parity and stop bit. Please note that no spaces are allowed within the Command Code and that only upper case characters will be accepted for that purpose. Your messages, however. may contain any ASCII character except, of course, Control D (EOT), line feed and carriage return which are reserved for their respective purposes.

You may leave a message for NAVOBSY whenever you get the USNO info prompt *. Terminate your call with CNTL D (EOT). This is important to make the program immediately available again. For interrupting a long file being read to you, send "BREAK" (CNTRL 2 on some TI Terminals). The requested identification can be of any length since we have a logfile on which everything incoming is kept.

You will obtain best results if you do not call during peak traffic, i.e., not between 9-12 a.m. and 1:30-5 p.m. EST, particularly on AUTOVON. If you should get poor results ("garbage") try to terminate and call again. Line quality can change greatly from one call to the next and tends to deteriorate during peak traffic time. Also make sure that

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your handset is seated firmly in the terminal rubber receptacles and that your microphone is working properly. Difficulties in access may be cured with slight transmit level adjustment on your terminal. Some of our callers have also noticed that trouble may exist on a particular extension and in this case it is your local line which has to be checked. The Phone Company also offers a "WEAK VOICE" amplifier for less than one dollar per month which will boost your modem level to compensate for a lossy line to your central office. Lines with too many extensions are more likely to be troublesome. Simply try a different telephone.

Since 300BD is different in respect to marginal conditions compared to 1200BD one should try both speeds if difficulties persist. If you use a computer to talk to us then please remember that our identification will come on automatically. However, there is a greater delay on 1200BD before we start transmitting compared to 300BD. It is therefore not necessary to send interrupts. Unless sent as breaks for interrupting reading of a long file, these interrupts will not speed up your access since the interface is insensitive to interrupts after your call has been answered.

Our normal operation uses ECHO. i.e., your terminal in full duplex writes what it gets back from us. For certain computer traffic, however, it may be advisable to turn off the ECHO. While we have three dummy (NULL) characters at 300BD to allow slow printers to follow, we do not have them at 1200BD. However, this can be changed by operator command. This command changes the operation into its opposite (but not back).

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Time Service Announcement Series 14, No. 27, 1980, available from U.S. Naval Observatory Time Service Division, Washington. D.C. 20390 U.S.A.

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