NAME

predict − Track and predict passes of satellites in Earth orbit

SYNOPSIS

predict [-u *tle_update_source*] [-t *tlefile*] [-q *qthfile*] [-a *serial_port*] [-n *network_port*] [-f *sat_name starting_date/time ending_date/time*] [-p *sat_name starting_date/time*] [-o *output_file*] [-s]

DESCRIPTION

PREDICT is a multi-user satellite tracking and orbital prediction program written under the Linux operating system by John A. Magliacane, KD2BD. **PREDICT** is free software. You can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 2 of the License or any later version.

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FIRST TIME USE

PREDICT tracks and predicts passes of satellites based on the geographical location of the ground station, the current date and time as provided by the computer system's clock, and Keplerian orbital data for the satellites of interest to the ground station. First time users of **PREDICT** are provided default ground station location and orbital data information files. These files are managed by the program, and are normally located in a user's home directory under a hidden subdirectory named *.predict*. First time users will be prompted to supply **PREDICT** with their geographical location (the same as selecting option **[G]** from the program's main menu) the first time the program is run. Latitude is entered in decimal degrees north. Latitudes south of the equator are entered as negative numbers. Longitude is entered as decimal degrees west. Eastern longitudes may be entered as negative numbers. Station altitude is entered as the number of meters the ground station is located above sea level. This parameter is not very critical. If unsure, make a realistic guess or simply enter 0.

Users of **PREDICT** need Keplerian orbital data for the satellites they wish to track that is preferably no older than one month. The default orbital data supplied with the program is liable to be quite old, and so must be brought up to date if accurate results are to be expected. This may be accomplished by selecting option **[E]** from **PREDICT's** main menu and manually entering Keplerian data for each satellite in the program's database, or by selecting option **[U]** and specifying a file containing recent 2-line Keplerian element data sets that correspond to the satellites in the program's database. Keplerian orbital data is available from a variety of sources, including *http://www.celestrak.com/* and *http://www.amsat.org/*.

PROGRAM OPERATION

The operation of **PREDICT** is uncomplicated by design. The start-up screen of the program lists the program's main functions. Several tracking and orbital prediction modes are available, as well as several utilities to manage the program's orbital database.

PREDICTING SATELLITE PASSES

Orbital predictions are useful for determining in advance when a satellite is expected to come within range of a ground station. They can also be used to look back to previous passes to help to confirm or identify past observations.

PREDICT includes two orbital prediction modes to predict any pass above a ground station (main menu option **[P]**), or list only those passes that might be visible to a ground station through optical means (main menu option **[V]**). In either mode, the user is asked to select a satellite of interest from a menu, and then asked to enter the date and time (in UTC) at which prediction calculations should start.

The current date and time may be selected by default by entering nothing and hitting simply the ENTER key when prompted to enter the starting date and time.

Otherwise, the starting date and time should be entered in the form:

DDMonYY HH:MM:SS

Entering the time is optional. If it is omitted, midnight (00:00:00) is assumed. Once complete, orbital calculations are started and prediction information is displayed on the screen.

The date and time in UTC, along with the satellite's elevation above ground, azimuth heading, modulo 256 orbital phase, sub-satellite point latitude and longitude, slant range between the ground station and the satellite, and the satellite's orbit number are all displayed. An asterisk (*) displayed to the right of the orbit number means the satellite is in sunlight at the date and time listed on the line. A plus symbol (+) means the satellite is in sunlight while the ground station is under the cover of darkness at the time and date listed. Under good viewing conditions, large satellites such as the International Space Station (ISS), the US Space Shuttles, and Hubble Space Telescope, and the Upper Atmosphere Research Satellite (UARS) are visible to the naked eye. If no symbol appears to the right of the orbit number, then the satellite is in the Earth's shadow at the time and date listed, and is not receiving any illumination from the sun.

Pressing the **ENTER** key, the '**Y**' key, or the space bar advances the orbital predictions to a screen listing the next available passes. Pressing the '**L**' key allows the currently displayed screen plus any subsequent screens to be logged to a text file in your current working directory. The name given to this file is the name of the satellite plus a ".txt" extension. Any slashes or spaces appearing in the satellite name are replaced by the underscore (_) symbol. The logging feature may be toggled on and off at any time by pressing the '**L**' key. Exiting the orbital prediction mode by pressing '**N**' or hitting the **ESC**ape key will also close the log file. The log file will be appended with additional information if additional predictions are conducted for the same satellite with the logging feature turned on.

Selecting **[V]** from **PREDICT's** main menu will permit a ground station to only predict passes for satellites that are potentially visible through optical means. Since all other passes are filtered out in this mode, and since some satellites may never arrive over a ground station when optical viewing conditions are possible, the program provides the option of breaking out of visual orbital prediction mode by pressing the **[ESC]**ape key as calculations are made. A prompt is displayed at the bottom of the screen to alert the user of this option.

In either orbital prediction mode, predictions will not be attempted for satellites that can never rise above the ground station's horizon, or for satellites in geostationary orbits. If a satellite is in range at the starting date and time specified, **PREDICT** will adjust the starting date back in time until the point of AOS so that the prediction screen displays the first pass in its entirety from start to finish.

SINGLE SATELLITE TRACKING MODE

In addition to predicting satellite passes, **PREDICT** allows satellites to be tracked singly in real-time using **PREDICT's** Single Satellite Tracking Mode (main menu option **[T]**), or simultaneously as a group of 24 using the program's Multi-Satellite Tracking Mode (main menu option **[M]**). The positions of the Sun and Moon are also displayed when tracking satellites in real-time.

Selecting option **[T]** from **PREDICT's** main menu places the program in Single Satellite Tracking Mode. The user will be prompted to select the satellite of interest, after which a screen will appear and display tracking positions for the satellite selected.

In Single Satellite Tracking Mode, the current date and time are displayed along with the satellite's subsatellite point, its orbital altitude in both kilometers and statute miles, the slant range distance between the ground station and the satellite in both kilometers and statute miles, the current azimuth and elevation headings toward the satellite, the orbital velocity of the satellite in both kilometers per hour and statute miles per hour, the footprint of the satellite in both kilometers and statute miles, the orbital phase of the satellite in both modulo 256 and 360, as well as the current orbit number. Additionally, if the satellite is currently in range of the ground station, the amount of Doppler shift experienced by the ground station receiving downlinks at 146 MHz and 435 MHz are displayed, as well as the one-way path loss for these frequencies. The predicted time of LOS as well as sunlight and visibility information are also displayed at the bottom of the screen. If the satellite is not in range, then the Doppler shift and path loss calculations are not performed, and the next predicted AOS date and time is shown at the bottom of the screen.

If a soundcard is present on your machine and the Single Satellite Tracking Mode is invoked with an uppercase '**T**' rather than a lowercase '**t**', **PREDICT** will make periodic voice announcements stating the satellite's tracking coordinates in real-time. Announcements such as:

"This is PREDICT. Satellite is at 5 6 degrees azimuth and 4 5 degrees elevation, and approaching."

are made at intervals that are a function of how quickly the satellite is moving across the sky. Announcements can occur as frequently as every 50 seconds for satellites in low earth orbits such as the International Space Station (370 km), or as infrequently as every 8 minutes for satellites in very high orbits, such as the GE-2 geostationary satellite (35780 km). Voice announcements are performed as background processes so as not to interfere with tracking calculations as the announcements are made. Announcements can be forced at any time by pressing the '**T**' key in Single Satellite Tracking Mode.

MULTI-SATELLITE TRACKING MODE

Selecting **[M]** from **PREDICT's** main menu places the program in a real-time multi-satellite tracking mode. In this mode, all 24 satellites in the program's database are tracked simultaneously along with the positions of the Sun and Moon. Tracking data for the satellites is displayed in two columns of 12 satellites each. The name, azimuth heading, elevation, sub-satellite point latitude (in degrees North) and longitude (in degrees West) positions are provided, along with the slant range distance between the satellite and the ground station (in kilometers).

A letter displayed to the right of the slant range indicates the satellite's sunlight and eclipse conditions. If the satellite is experiencing an eclipse period, an **N** is displayed. If the satellite is in sunlight and the ground station is under the cover of darkness, a **V** is displayed to indicate the possibility that the satellite is visible under the current conditions. If the satellite is in sunlight while conditions at the ground station do not allow the satellite to be seen, a **D** is displayed. Satellites in range of the ground station are displayed in **BOLD** lettering. The AOS dates and times for the next three satellites predicted to come into range are displayed on the bottom of the screen between the tracking coordinates of the Sun and Moon. Predictions are not made for satellites in geostationary orbits or for satellites so low in inclination and/or altitude that they can never rise above the horizon of the ground station.

SOLAR ILLUMINATION PREDICTIONS

Selecting **[S]** from **PREDICT's** main menu will allow solar illumination predictions to be made. These predictions indicate how much sunlight a particular satellite will receive in a 24 hour period. This information is especially valuable to spacecraft designers and satellite groundstation controllers who must monitor spacecraft power budgets or thermal conditions on-board their spacecraft due to sunlight and eclipse periods. It can even be used to predict the optimum times for astronauts to perform extra-vehicular activities in space. Solar illumination predictions may be logged to a file in the same manner that orbital predictions may be logged (by pressing **L**).

OPERATING UNDER THE X-WINDOW SYSTEM

PREDICT may be run under the X-Window System by invoking it through the *xpredict* script contained with this software. *xpredict* can invoke *rxvt*, *xterm*, *Eterm*, *gnome-terminal*, or *kvt*, and display **PREDICT** in a virtual terminal window. *xpredict* should be edited for best results. In many cases, holding down the SHIFT key while pressing the plus (+) and minus (-) keys allows **PREDICT's** window to be re-sized when started under *xpredict*.

COMMAND LINE ARGUMENTS

By default, **PREDICT** reads ground station location and orbital data information from a pair of files located in the user's home directory under a hidden subdirectory named *.predict*. Ground station location information is held in a file named *predict.qth*, while orbital data information for 24 satellites is held in a file named *predict.tle*.

If we wish to run **PREDICT** using data from alternate sources instead of these default files, the names of such files may be passed to **PREDICT** on the command line when the program is started. For example, if we wish to read the TLE file *visual.tle* and the QTH file *holiday.qth* rather than the default files, we could start **PREDICT** and pass the names of these alternate files to the program in the following manner:

predict -t visual.tle -q holiday.qth

or

predict -q holiday.qth -t visual.tle

If the files specified are not located in the current working directory, then their relative or absolute paths should also be specified along with their names (*predict -t /home/kd2bd/orbs/visual.tle*).

It is also possible to specify only one alternate file while using the default for the other. For example,

predict -t visual.tle

reads QTH information from the default *~/.predict/predict.qth* location, and TLE information from *visual.tle*, while

predict -q bobs.qth

reads QTH information from *bobs.qth* and TLE information from the default *~/.predict/predict.tle* location.

QUIET ORBITAL DATABASE UPDATES

It is also possible to update **PREDICT's** satellite orbital database using another command line option that updates the database from a NASA two-line element data set. **PREDICT** then quietly exits without displaying anything to the screen, thereby eliminating the need for entering the program and selecting the appropriate menu options. This option is invoked using the *-u* command line switch as follows:

predict -u orbs248.tle

This example updates **PREDICT's** default orbital database with the Keplerian elements found in the file *orbs248.tle*. **PREDICT** may be updated from a list of files as well:

predict -u amateur.tle visual.tle weather.tle

If an alternate datafile requires updating, it may also be specified on the command line using the *-t* switch as follows:

predict -t oscar.tle -u amateur.tle

This example updates the *oscar.tle* orbital database with the two-line element data contained in *amateur.tle*.

These options permit the automatic update of **PREDICT's** orbital data files using Keplerian orbital data obtained through automatic means such as FTP, HTTP, or pacsat satellite download.

For example, the following script can be used to update **PREDICT's** orbital database via the Internet:

```
#!/bin/sh
wget -qc www.celestrak.com/NORAD/elements/amateur.txt -O amateur.txt
wget -qc www.celestrak.com/NORAD/elements/visual.txt -O visual.txt
wget -qc www.celestrak.com/NORAD/elements/weather.txt -O weather.txt
/usr/local/bin/predict -u amateur.txt visual.txt weather.txt
```

To truly automate the process of updating your orbital database, save the above commands to a file in your home directory (such as *kepupdate*), and add the following line to your crontab (type *crontab -e* to edit your crontab):

*0 2 * * * kepupdate*

and **PREDICT** will automatically update its database every day at 2:00 AM.

AUTOMATIC ANTENNA TRACKING

Using the PIC/TRACK antenna rotator interface created by Vicenzo Mezzalira, IW3FOL <http://digilander.iol.it/iw3fol/pictrack.html>, **PREDICT** can automatically control the position of AZ/EL antenna rotators, and keep antennas accurately pointed toward a satellite being tracked by **PREDICT**. The PIC/TRACK interface connects between the PC's serial port and the antenna rotators. Tracking data from **PREDICT** is directed to the appropriate serial port using the *-a* command line option. For example:

predict -a /dev/ttyS0

will send tracking data to the first serial port when the program is tracking a satellite in the Single Satellite Tracking Mode. The data sent to the serial port is of the form: *"AZ241.0 EL26.0"*.

ADDITIONAL OPTIONS

The *-f* command-line option, when followed by a satellite name or object number and starting date/time, allows **PREDICT** to respond with satellite positional information. This feature allows **PREDICT** to be invoked within other applications that need to determine the location of a satellite at a particular point in time, such as the location of where a CCD camera image was taken by a Pacsat satellite based on its timestamp.

The information produced includes the date/time in Unix format (the number of seconds since midnight UTC on January 1, 1970), the date/time in ASCII (UTC), the elevation of the satellite in degrees, the azimuth heading of the satellite, the orbital phase (modulo 256), the latitude (N) and longitude (W) of the satellite's sub-satellite point at the time specified, the slant range to the satellite in kilometers with respect to the ground station's location, the orbit number, and the spacecraft's sunlight visibility information.

The date/time must be specified in Unix format (number of seconds since midnight UTC on January 1, 1970). If no starting or ending time is specified, the current date/time is assumed and a single line of output is produced. If a starting and ending time are specified, a list of coordinates beginning at the starting time/date and ending with the ending time/date will be returned by the program with a one second resolution. If the letter *m* is appended to the ending time/date, then the data returned by the program will have a one minute resolution. The *-o* option allows the program to write the calculated data to an output file rather than directing it to the standard output device if desired.

The proper syntax for this option is as follows:

predict -f ISS 977446390 977446400 -o datafile

A list of coordinates starting at the current date/time and ending 10 seconds later may be produced by the following command:

predict -f ISS +10

If a list of coordinates specifying the position of the satellite every minute for the next 10 minutes is desired, the following command may be used:

predict -f ISS +10m

If a satellite name contains spaces, then the entire name must be enclosed by "quotes".

The *-p* option allows orbital predictions for a single pass to be generated by **PREDICT** via the command-line. For example:

predict -p OSCAR-11 1003536767

starts predictions for the OSCAR-11 satellite at a Unix time of 1003536767 (Sat 20Oct01 00:12:47 UTC). If the starting date/time is omitted, the current date/time is used. If a pass is already in progress at the starting date/time specified, orbital predictions are moved back to the beginning of AOS of the current pass, and data for the entire pass from AOS to LOS is provided.

When either the *-f* or *-p* options are used, **PREDICT** produces an output consisting of the date/time in Unix format, the date and time in ASCII (UTC), the elevation of the satellite in degrees, the azimuth of the satellite in degrees, the orbital phase (modulo 256), the latitude (N) and longitude (W) of the satellite's sub-satellite point, the slant range to the satellite (in kilometers), the orbit number, and the spacecraft's sunlight visibility information. For example:

```
1003611710 Sat 20Oct01 21:01:50   11    6  164   51   72   1389  16669 *
```

The output isn't annotated, but then again, it's meant to be read by other software.

SERVER MODE

PREDICT's network socket interface allows the program to operate as a server capable of providing tracking data and other information to client applications using the UDP protocol. It is even possible to have the **PREDICT** server and client applications running on separate machines provided the clients are connected to the server through a functioning network connection.

The *-s* switch is used to start **PREDICT** in server mode:

predict -s

By default, **PREDICT** uses socket port 1210 for communicating with client applications. Therefore, the following line needs to be added to the end your */etc/services* file:

predict 1210/udp

The port number (1210) can be changed to something else if desired. There is no need to recompile the program if it is changed. To run more than one instance of **PREDICT** in server mode on a single host, an alternate port must be specified when invoking the additional instances of **PREDICT**. This can be accomplished by using the *-n* switch:

predict -n 1211 -t other_tle_file -s

When invoked in server mode, **PREDICT** immediately enters Multi-Satellite Tracking Mode, and makes live tracking data available to clients. Clients may poll **PREDICT** for tracking data when the program is running in either the Multi-Satellite or Single Satellite Tracking Mode. When in Multi-Satellite Tracking mode, tracking data for any of the 24 satellites in the program's database may be accessed by client applications. When in Single-Satellite Tracking mode, only live tracking data for the single satellite being tracked may be accessed. Either tracking mode may be ended at any time. When this is done, **PREDICT** will return the last calculated satellite tracking data until the program is again put into a real-time tracking mode. This allows the user to return to the main menu, and use other features of the program without sending potentially harmful data to client applications.

The best way to write a client application is to use the demonstration program (demo.c) included in this distribution of **PREDICT** as a guide. The sample program has comments to explain how each component operates. It is useful to pipe the output of this program through *less* to easily browse through the data returned (*demo* | *less*).

In operation, a character array is filled with the command and arguments to be sent to **PREDICT**. A socket connection is then opened, the request is sent, a response is received, and the socket connection is closed. The command and arguments are in ASCII text format.

Several excellent network client applications are included in this release of **PREDICT**, and may be found under the *predict/clients* directory.

ADDING SATELLITES

One of the most frequently asked questions is how satellites in **PREDICT's** orbital database may be added, modified, or replaced. As it turns out, there are several ways in which this can be done. Probably the easiest is to manually edit your *~/.predict/predict.tle* file, and replace an existing satellite's entry with 2-line Keplerian data for the new satellite. If this method is chosen, however, just make sure to include ONLY the two line data, and nothing else.

Another way is to is select the Keyboard Edit option from the program's Main Menu, select a satellite you wish to replace. Edit the name and object number (replacing the old information with the new information). Just hit ENTER, and accept all the other orbital parameters shown. Get back to **PREDICT's** Main Menu. Select Auto Update, and then enter the filename containing the 2-line element data for your favorite new satellite. The new satellite data should be detected by **PREDICT**, and the orbital data for the old satellite will be overwritten by the new data.

NEAT TRICKS

In addition to tracking and predicting passes of satellites, **PREDICT** may also be used to generate a NASA two-line Keplerian element data set from data entered via keyboard. For example, let's say you're listening to Space Shuttle audio re-broadcasts via WA3NAN and Keplerian elements for the Space Shuttle's orbit are given by the announcer. The orbital data provided by WA3NAN in verbal form may be manually entered into **PREDICT's** orbital database using option **[E]** of the program's main menu (Keyboard Edit of Orbital Database). The orbital data for the Space Shuttle in NASA two-line element form can then be found in your orbital database file, and may imported to any other satellite tracking program that accepts two-line element files or distributed to others electronically.

It is also possible to run **PREDICT** as a background process and direct its display to an unused virtual console by using the following command:

predict < /dev/tty8 > /dev/tty8 &

Switching to virtual console number 8 (ALT-F8 in text mode) will allow **PREDICT** to be controlled and displayed even after you've logged out. This is especially handy when running **PREDICT** in server mode on a remote machine.

GLOSSARY OF TERMS

The following terms are frequently used in association with satellite communications and space technology:

AOS:

Acquisition of Signal - the time at which a ground station first acquires radio signals from a satellite. **PREDICT** defines AOS as the time when the satellite being tracked comes within +/- 0.03 degrees of the local horizon, although it may have to rise higher than this before signals are first heard.

Apogee:

Point in a satellite's orbit when the satellite is at its farthest distance from the earth's surface.

Anomalistic Period:

A satellite orbital parameter specifying the time between successive perigees.

Ascending Node:
Point in a satellite's orbit when its sub-satellite point crosses the equator moving south to north.

Azimuth:
The compass direction measured clockwise from true north. North = 0 degrees, East = 90 degrees, South = 180 degrees, and West = 270 degrees.

Descending Node:
Point in a satellite's orbit when its sub-satellite point crosses the equator moving north to south.

Doppler Shift:
The motion of a satellite in its orbit around the earth, and in many cases the rotational motion of the earth itself, causes radio signals generated by satellites to be received on Earth at frequencies slightly different than those upon which they were transmitted. **PREDICT** calculates what effect these motions have upon the reception of satellites transmitting on the 146 MHz and 435 MHz Amateur Radio bands.

Elevation:
The angle between the local horizon and the position of the satellite. A satellite that appears directly above a particular location is said to be located at an elevation of 90 degrees. A satellite located on the horizon of a particular location is said to be located at an elevation of 0 degrees. A satellite with an elevation of less than zero is positioned below the local horizon, and radio communication with a satellite in such a position is not possible under normal circumstances.

Footprint:
Diameter of the Earth's surface visible from a satellite. The higher the satellite's orbital altitude, the greater the footprint, and the wider the satellite's communications coverage.

LOS:
Loss of Signal - the time at which a ground station loses radio contact with a satellite. **PREDICT** defines LOS as the time when the satellite being tracked comes within +/- 0.03 degrees of the local horizon.

Orbital Phase:
An orbital "clock" that describes a satellite's orbital position with respect to perigee. Orbital Phase may be modulo 256, or modulo 360, and is sometimes referred to as mean anomaly when speaking of amateur radio satellites in elliptical orbits, such as the Phase 3 satellites. Orbital phase is zero at perigee.

Path Loss:
The apparent attenuation a radio signal undergoes as it travels a given distance. This attenuation is the result of the dispersion radio waves experience as they propagate between transmitter and receiver using antennas of finite gain. Free space path loss is technically an oxymoron since free space is loss free.

Perigee:
Point in a satellite's orbit when the satellite is at its closest distance to the earth's surface.

Nodal Period:
A satellite orbital parameter specifying the time between successive ascending nodes.

Slant Range:
The straight line distance between the ground station and the satellite at a given time.

Sub-Satellite Point:
The latitude and longitude specifying the location on the Earth that is directly below the satellite.

ADDITIONAL INFORMATION

Detailed information on the operation of **PREDICT's** UDP socket-based interface as well as sample code for writing your own client applications is available in the *predict/clients/samples* subdirectory. The latest news is available through the official **PREDICT** software web page located at: <http://www.qsl.net/kd2bd/predict.html>.

FILES

`~/.predict/predict.tle`
Default database of orbital data

`~/.predict/predict.qth`
Default ground station location information

AUTHORS

PREDICT was written by John A. Magliacane, KD2BD <kd2bd@amsat.org>. The socket server code was contributed by Ivan Galysh, KD4HBO <galysh@juno.nrl.navy.mil>. The PIC/TRACK serial port antenna rotator controller code was contributed by Vittorio Benvenuti, I3VFJ <benscosm@iol.it>.