NAME

predict − Track and predict passes of satellites in Earth orbit.

SYNOPSIS

predict [-u *tle_update_source*] [-t *tlefile*] [-q *qthfile*] [-f *sat_name starting_date/time ending_date/time*] [-dp *sat_name starting_date/time ending_date/time*] [-p *sat_name starting_date/time*] [-o *output_file*] [-s] [-east] [-west] [-north] [-south]

DESCRIPTION

PREDICT is a multi-platform 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.

PREDICT is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY, without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

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 located under **PREDICT**'s installation directory. First time users should supply**PREDICT** with their geographical location by selecting option **[G]** from the program's main menu. Latitude is normally expressed in degrees north with latitudes south of the equator expressed in negative degrees. Longitude is normally expressed in degrees west (0-360) with eastern longitudes expressed in negative degrees. This behavior can be modified by passing the *-east* or *-south* commmand line switches to **PREDICT**.

Latitudes and longitudes may be either entered in decimal degrees, or in degrees, minutes, seconds (DMS) format. 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 *https://www.celestrak.com/NORAD/elements/*, *https://www.amsat.org/tle/current/nasa.all*, and *https://www.space-track.org/*.

PROGRAM OPERATION

The start-up screen of **PREDICT** 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. If spacecraft attitude parameters (ALAT, ALON) are included in **PREDICT's** transponder database file, then spacecraft antenna squint angles are displayed instead of orbit numbers in the orbital prediction output.

An asterisk (*) displayed to the right of the orbit number or squint angle 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) and the Hubble Space Telescope are visible to the naked eye. If no symbol appears to the right of each line, 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 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 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, a wealth of information related to tracking a spacecraft and communicating through its transponder is displayed. The current date and time is displayed along with the satellite's sub-satellite 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 modulo 256 orbital phase of the satellite, the eclipse depth, the spacecraft antenna squint angle, and orbital model in use, as well as the current orbit number are also displayed. The date and time for the next AOS is also provided.

Additionally, if the satellite is currently in range of the ground station, the amount of Doppler shift experienced on uplink and downlink frequencies, path loss, propagation delay, and echo times are also displayed. The expected time of LOS is also provided.

Uplink and downlink frequencies are held in **PREDICT's** transponder database file, *predict.db*.

Transponders may be sequenced by pressing the SPACE BAR. The passband of the transponder may be tuned in 1 kHz increments by pressing the < and > keys. 100 Hz tuning is possible using the**,** and **.** k eys. (These are simply the **<** and **>** keys without the SHIFT key.)

If no transponder information is available, the data displayed on the tracking screen is abbreviated.

The features available in the Single Satellite Tracking Mode make it possible to accurately determine the proper uplink frequency to yield a given downlink frequency, or vice versa. For example, if one wishes to communicate with a station heard on 435.85200 MHz via FO-29, then 435.85200 MHz can be selected via the keyboard as an RX frequency using the tuning keys while tracking FO-29, and the corresponding ground station TX frequency will be displayed by **PREDICT**.

Obviously, an accurate system clock and up-to-date orbital data are required for the best tuning accuracy.

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 per calendar day. This information is especially valuable to spacecraft designers and satellite ground station 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**).

SOLAR AND LUNAR ORBITAL PREDICTIONS

In addition to making orbital predictions of spacecraft, **PREDICT** can also predict transits of the Sun and the Moon. Lunar predictions are initiated by selecting **[L]** from **PREDICT**'s Main Menu. Solar predictions are selected through Main Menu option **[O]**.

When making solar and lunar orbital predictions, **PREDICT** provides azimuth and elevation headings, the right ascension, declination, Greenwich Hour Angle (GHA), radial velocity, and normalized distance (range) to the Sun or Moon. Declination and Greenwich Hour Angle correspond to the latitude and longitude of the object's sub-satellite point above the Earth's surface. The radial velocity corresponds to the speed and direction the object is traveling toward (+) or away (-) from the ground station, and is expressed in meters per second. When the radial distance of the Moon is close to zero, the amount of Doppler shift experienced in Moonbounce communications is minimal. The normalized distance corresponds to the object's actual distance to the ground station divided its average distance. In practice, the normalized distance can range from about 0.945 to 1.055 for the Moon, and about 0.983 to 1.017 for the Sun.

Note that the effects of atmospherics are ignored in determining the elevation angles for the Sun and Moon. Furthermore, the data provided by **PREDICT** corresponds to the object's center, and not the upper or lower limb, as is sometimes done when predicting the rising and setting times of these celestial objects.

COMMAND LINE ARGUMENTS

By default, **PREDICT** reads ground station location and orbital data information from a pair of files located in the user's current working directory. 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 *beach_house.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 beach_house.qth

or

predict -q beach_house.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.

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.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.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.

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 and longitude 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 ha ve 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

or

predict -f 25544 977446390 977446400 -o datafile

Note that referencing a satellite by its object number rather than by its name is the preferred practice when the name is especially long.

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 1602514800

starts predictions for the OSCAR-11 satellite at a Unix time of 1602514800 (Monday October 12, 2020 at 15:00:00 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, the spacecraft's sunlight visibility information, and, if the satellite is in range, 100 MHz-normalized downlink Doppler shift information.

For example:

```
1589489403 Thu 14May20 20:50:03   20   65  209   45   57   1766  38901 *
74.989726
```

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

The *-dp* option produces a quick orbital prediction for the next pass of a specified satellite, including 100 MHz downlink Doppler shift information, in CSV format. For example:

predict -dp ISS

produces:

```
1606164834,Mon 23Nov20 20:53:54,2117.968361
1606164837,Mon 23Nov20 20:53:57,2113.980313
1606164841,Mon 23Nov20 20:54:01,2109.841840
1606164844,Mon 23Nov20 20:54:04,2105.547640
1606164848,Mon 23Nov20 20:54:08,2101.092181
<... output trimmed ...>
1606165427,Mon 23Nov20 21:03:47,-2118.504745
1606165431,Mon 23Nov20 21:03:51,-2122.521853
1606165434,Mon 23Nov20 21:03:54,-2126.393648
1606165438,Mon 23Nov20 21:03:58,-2130.125091
1606165441,Mon 23Nov20 21:04:01,-2133.720808
```

where the Unix time is followed by the UTC date/time and 100 MHz downlink-referenced Doppler shift. The satellite name or object number can be followed by a starting date/time and ending date/time much like the *-f* option.

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.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 through the keyboard by using **PREDICT's** Main Menu option **[E]**. The 2-Line orbital data for the satellite(s) in question may be found in your orbital database file, and can be imported to any other satellite tracking program that accepts two-line element files or distributed to others electronically in this format.

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

The latest news is available through the official **PREDICT** software web page located at: <http://www.qsl.net/kd2bd/predict.html>.

FILES

`predict.tle`

Default database of orbital data

`predict.db`

Satellite transponder database file

`predict.qth`

Default ground station location and timezone offset relative to UTC

AUTHORS

PREDICT was written by John A. Magliacane, KD2BD <kd2bd@amsat.org>. SGP4/SDP4 code was derived from Pacsal routines written by Dr. T.S. Kelso, and converted to 'C' by Neoklis Kyriazis, 5B4AZ. See the CREDITS file for additional information.