


SatTrak[®] by Mike Pflueger WD8KPZ

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About SatTrak

SatTrak is a utility program designed primarily for Amateur Radio operators interested in satellite communications. It also contains a few other functions which may be of more general interest to hams - Great Circle distance and Bearing (for pointing beams for HF communications), Maximum Usable Frequency (MUF) plots, Grid locator identifiers, Radio Horizon for determining the line of sight distance between two antennas, useful for VHF frequencies and above, and wavelength calculations useful for many things such as constructing antennas or matching transformers.

SatTrak comes as a demo version, which means that Save, Copy, and Print are disabled. These functions will be enabled after you pay the shareware fee and get a password from the author. Also this will prevent the "About" screen from popping up every time you open the program.

If you use it, I ask that you please pay the shareware fee as I have put a lot of time and effort into the program. If you haven't paid, don't expect me to support it. Comments, suggestions, and bug reports are welcomed. If you pass the program on, please pass it as a demo version (password never entered) and pass this document with it. Sorry, I don't distribute the source code.

If you can't download from the network, send a floppy (800K or 1.4M) and a prepaid mailer to the following address and I'll send you the program:

SatTrak
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Features

- Generate a detailed, customizable plot of when a particular satellite will be visible from a given location, its position, altitude, and many other items
 - Given operation mode data for a satellite, tells you what mode the satellite is operating in
- Generate a list of satellites currently visible from a given location
 - Display (on a world map) a satellite's position at any point in time
 - Display in real time (on a world map) a satellite's current location
 - Generate beam headings between two locations
 - Find grid identifier (Maidenhead grid locator) of any location
 - Generate MUF plots between any two locations for any day
- Generate band openings from a selected location to various points around the world
- Find the line-of-sight distance between antennas at two elevations
- Given a frequency, gives the half and quarter wavelengths, and second and third harmonic frequencies - and shows a simple dipole antenna design (HF or VHF)
- Convert NASA format element sets to Keplerian format
 - Print or save windows to a file, copy text or

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pictures to other programs

- Saves data for up to 200 satellites, 20 ground locations, and mode data for up to 20 satellites
- Preferences (metric or English, UTC or local, data to output)
 - Help panels
 - Color pictures. System 7 friendly (sorry, no balloon help yet)

Copyright, Shareware, and Distribution Notices

SatTrak is written with Think Pascal™, so portions are Copyright © Think Technologies, Inc. The rest is Copyright © Mike Pflueger, 1990. This program is shareware: you may distribute it freely so long as it is complete and unaltered, and as long as no fee is charged for the program or distribution thereof (except normal connect fees in the case of BBS's). After 15 days you must pay the requested fee to the author or dispose of the program.

Getting Started

Preferences Files

SatTrak uses 4 settings files called “preferences” files since they store your data and preferred settings for the program - your preferences. SatTrak expects to find these files in the “Preferences” folder inside the active system folder (or in the system folder itself) under these *exact* names:

- **SatTrak Config** - contains your preferred general configuration settings for the program - preferences, distance units, and time format
- **SatTrak Sites** - contains your preferred station site(s) on which satellite calculations are based. Each site has a name, location (latitude and longitude), local time difference from UTC (GMT or “Zulu”), site altitude (above sea level), and a minimum satellite visibility angle.
- **SatTrak Elements** - This file contains the orbital elements in Keplerian format for all satellites of interest. Automatically loaded at startup time (see below).
- **SatTrak Satellite Modes** - This file contains operational mode information for up to 20 satellites. Usually used for the OSCAR’s.

If you are missing one or more of these files, SatTrak will create a default for each file it doesn’t find. Site, Modes, and Config files are changed as you change settings (add or delete sites, change output format preferences) from within SatTrak. Elements files are normally “imported” by SatTrak from some other source.

When you first install SatTrak, you’ll find a file called **SatTrak Elements** included with the program. Before launching SatTrak, copy this file into your Preferences folder: open your System Folder, locate the folder called **Preferences**, then drag the **SatTrak Elements** file on top of the **Preferences** folder and drop it there. If you have no folder called **Preferences**, you can create one or simply drop the **SatTrak Elements** file inside the system folder.

More details on SatTrak Preferences

SatTrak looks for these 4 preferences files when it starts up. It follows the following process once for *each* of the 4 files *every time* it starts up:

- 1
1. It looks in the startup System Folder for a folder called Preferences, then looks in there for a file with the exact name that it is looking for (for example, "SatTrak Elements"). If found, it skips to step 4.
- 2
2. If no folder named Preferences exists in the startup System Folder, SatTrak looks for the file in the System Folder. If found, it skips to step 4.
- 3
3. If SatTrak has still not found a file with the exact name that it was looking for, it will create a folder called Preferences inside your System Folder. In there, it will create a copy of the file that it was looking for and initialize it with default information. For the elements file, for example, it inserts an element set for satellite "Alouette".
- 4
4. The file is now opened and the contents read and validated. If all 4 of the files have not yet been opened, SatTrak decides which is the next one to be opened and returns to step 1.
- 5
5. Once all 4 files are opened, SatTrak is ready to use, and will remove the "Reading Configuration Files" message. By choosing Info on the File menu, SatTrak will show you where all 4 currently open files are located. Note that the files can be in either the System Folder or the Preferences folder, but if you have a file with the same name in both folders, SatTrak will open the one in the Preferences folder because that's where it looks first.

So, when you first use SatTrak, if you haven't placed a file called "SatTrak Elements" in either your Preferences or System Folder, it will create a default one for you and open it. If you want to replace it with element sets you obtain from somewhere else (or the one that comes with SatTrak), just quit SatTrak and move the new element set into the folder containing the old element set, thus replacing it. Now when you start SatTrak, it should open the new element set.

Where do I get orbital elements?

Good question. These are available on many ham packet and telephone modem bulletin board systems, networks such as Compuserve and USENET (posted weekly to sci.space.news and rec.radio.info), and are occasionally found in publications. The NASA format elements posted on USENET (which SatTrak will convert with no formatting problems) are also available via anonymous FTP from **archive.afit.af.mil** (129.92.1.66) in the pub/space directory - updated about every 2 days. Current space shuttle elements are also posted here. One telephone BBS is the Celestial BBS at 513-253-9767 300/1200/2400/9600 8/1/none.

You should try to update the elements you use every few weeks because they *do* get out of date due to various forces acting on the satellites (like orbital correction burns, friction) which can't be precisely anticipated.

Using other orbital elements or modifying the elements file

SatTrak expects to read satellite element sets from a plain text file. These files can be created or edited with any text editor or word processor (some editors can only open files less than 32K, and SatTrak Elements files can be larger than that). The elements should be in one of two particular formats - Keplerian or NASA. Keplerian format is SatTrak's preferred format. NASA "two line" format may also be read in and converted to Keplerian for use by SatTrak (use the Configure menu option NASA to Keplerian...). SatTrak is pretty picky about what it gets, so make sure the format is correct (see the Appendices in this document on the two formats). It does, however, try to be specific about what it doesn't like if it comes across bad data so it's easier for you to find and correct.

NOTE: if you edit the elements with a word processor, make sure you save the file as “plain text”. SatTrak will only read element files of type TEXT.

SatTrak will read in Keplerian orbital elements for as few as 1 or many as 200 satellites. I recommend that you pare your elements file down to something more manageable because this makes for *very* long menus! Also, satellites menus are built in the order they are read in from the elements file. If you want them reorganized or alphabetized, you’ll can do that yourself with your word processor or text editor.

If you wish to use other elements files or modify your existing elements, you have several options:

- Modify your existing SatTrak Elements file (in your preferences folder): use this option if you want to permanently add a satellite to your list and have it automatically loaded when SatTrak starts up.
- Replace your existing SatTrak Elements file (in your preferences folder): use this option if you’ve obtained completely new element sets and want to permanently replace the list that is automatically loaded when SatTrak starts up. Remember that anything you modified in the old file will be lost.
- Save the elements in a separate file: use this option if you want to keep the elements around only a short time, if they’re satellites you use infrequently, or if you don’t want them loaded automatically when you start SatTrak.

Remember that the elements file must be called “SatTrak Elements” and must be in your System/Preferences folder to be automatically loaded on startup. However, once SatTrak is running, SatTrak offers a way to switch to other elements files.

The Use other elements... option on the Configure menu allows you to open and use *any* valid element set while SatTrak is running. So, for example, if you have a file in some other folder on your hard disk and it’s called “My Favorite Satellites”, just choose Use other elements..., move to the correct disk and folder, select the file and click Open. That element file will be loaded, replacing any previously loaded element sets, and will be used until you quit SatTrak *or* open another element file. The next time you start

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SatTrak, it goes back to looking for “SatTrak Elements” in Preferences or System Folder. The Info... option under the File menu will tell you the current elements file in use as well as the number of satellites in that file.

Element Set Format

When reading in element sets, SatTrak expects to find the exact formats shown in the Appendix. It looks at each line and expects to find the ***exact*** text of the next expected line in a data block followed by a value. There should be a blank line (carriage return only) between each data block.

[Hackers note: the expected strings, like all SatTrak I/O strings, may be found and modified in STR# resources. However only specific search strings can be changed, not the ordering or the data block format. This may be useful for converting SatTrak to another language. Remember, only modify a *copy* of the program, not the original.]

When SatTrak finds a problem while loading (or converting) an element set, it attempts to describe the problem and tell you where in the file it occurred. For example, it may say “Expected text not found at line n”. That means that there is some problem at the “n”th line of the elements file that you’re trying to load. To aid in “debugging” bad element files, SatTrak usually will also tell you what it was expecting and what it found instead. At this point you should look in the element file and compare what’s there with the format in the Appendix. SatTrak should be reasonably robust in catching and reporting incorrect elements files, but there is always the possibility of a crash if the file contains something I didn’t anticipate.

Some common problems are checksum lines in Keplerian elements; using a non-numeric string in the “Catalog Number” field; typos; and comments - either on separate lines or on the same line as data.

For a good example of a valid format, look at the “SatTrak Elements” file that came with SatTrak.

Here are a couple of examples of good and bad element sets:

Wrong:

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Right:

Page:

Using SatTrak

Note that SatTrak will work in the time (Local or UTC) and distance (metric or English) formats you specify in the “Preferences” configuration settings. ***It expects all input in the same units used for output.*** So if you want output in UTC, input date and time must also be in UTC. If you want output to be local date and time, input date and time must also be local.

Keyboard Shortcuts

SatTrak was designed to allow you to use keyboard shortcuts in many cases.

As with all Macintosh™ applications, a command key equivalent is listed in the menu as a shortcut for that menu selection. For example, to print, you may press command-P (⌘-P) instead of using the mouse to select the menu option.

In dialog boxes, outlined buttons are the defaults - you may press Enter or Return to select the default. In most dialogs, SatTrak also recognizes the first key of the button name. For example, in the Beam Heading dialog, once you’ve entered the desired latitude and longitude, you may press “m” to do a MUF plot.

SatTrak also recognizes the help button (for those keyboards with this key) and command-? (⌘-?) to bring up the help panels.

The Menus

SatTrak will only enable menu options which are valid for that point in time. For example, if a window can’t be printed (such as the Great Circle window), the Print option on the File menu will be dimmed.



About SatTrak... - contains general information on the program and access to help panels for the program.

File

Close - your standard "close window" option. Closes the window and offers to save the file.

Save, Save As - again the standard options to allow you to save the window as a file. SatTrak files are saved as ASCII text (for text-only windows, such as orbit plots) or PICT (for graphical windows such as MUF and position plots) and can thus be read by other programs such as word processors, spreadsheets, and graphics programs (MacDraw, MacPaint). In fact, spreadsheets like Excel can come in handy for manipulating orbit plot tables. SatTrak will not reopen or print files that have been previously saved since it does not permit editing of the data. This can be done with any word processor, editor, spreadsheet, or graphics program as applicable. To open a SatTrak document from another program, start that program, then choose its Open option and select the desired SatTrak file.

Save, Print, and Copy are disabled in demo versions of SatTrak. They can be enabled by entering the correct password supplied when you pay the shareware fee.

Page Setup - standard, used to select printer options.

Print - print the currently displayed SatTrak window.

Save, Print, and Copy are disabled in demo versions of SatTrak. They can be enabled by entering the correct password supplied when you pay the shareware fee.

Info - lists some useful information about the

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current status of SatTrak, such as what configuration, site, and element files are in use, and how many sites and satellites are in those files.

Quit - quit SatTrak. Offers to save any open windows which have not yet been saved.

Edit

Copy - the only edit option which SatTrak will ever allow. Allows you to copy selected text to be pasted in other applications or DA's. If a picture window (MUF plot or position plot) is displayed, choosing copy will copy the entire picture (PICT format) which can then be pasted in any program that accepts graphics.

Save, Print, and Copy are disabled in demo versions of SatTrak. They can be enabled by entering the correct password supplied when you pay the shareware fee.

Plot

A maximum of 5 orbit and position windows may be open. Orbit windows may contain a maximum of 32K of information each. Any orbit plot which attempts to exceed this limit will be terminated with a warning when the limit is reached.

Orbits... - Plots a table containing position of the satellite relative to the site over a period of time. Enter the starting date and hour in UTC or local time as selected under Preferences..., the length of the plot in days, and the step size. Select a satellite and site from the popup menus. When all information is correct, press enter or click on the calculate button to calculate and display the table. For details on the content of the output, see the section on Preferences... below. Due to the intensive nature of the calculations, this process of building the table is slow. You should exercise restraint when choosing a step size and duration. For example, if you select a step size of 1 minute and a duration of 2 days, SatTrak must calculate the position of the

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satellite 2880 times (the number of minutes in 2 days). If you chose a 10 minute step instead, this is only 288 iterations - however your resolution is more coarse and you may miss the minute the satellite pops above the horizon. It may therefore be more efficient to first do a plot with a 10 minute step size and a short duration to get a rough idea of where the satellite is, then do a more detailed (1 minute resolution) plot around the time of interest. Orbit plots are saved as ASCII text and can be read by other programs such as word processors and spreadsheets. In fact, spreadsheets like Excel can come in handy for manipulating orbit plot tables. SatTrak will not reopen or print files that have been previously saved. This can be done with any word processor, editor, or spreadsheet.

Position... - Given the date and time, and for a selected satellite, plots the position of the satellite at that moment. This is displayed on a world map and also in text form. The text will state if the satellite is currently eclipsed and if it is visible from the selected site. If the satellite is visible, SatTrak will display azimuth, elevation, doppler, and range information as configured under Preferences.... If the window is saved, only the text is saved for compatibility with all word processors and editors.

Current Position... - Displays the real-time position of a selected satellite. Based on the selected site, azimuth and elevation will be displayed if the satellite is visible.

Visible... - Given the date and time, and for a selected site, lists all of the satellites visible at that moment (as defined by the minimum elevation setting for that site). SatTrak will also display azimuth and elevation for each of these satellites.

Beam Heading & MUF - Opens a window which will calculate the Great Circle distance and bearing between two locations on the earth. The first site defaults to the latitude and longitude of the most recently used site. It can be changed if desired. You need to fill in the latitude and longitude of the destination site. Latitude and Longitude can be quickly entered from the stored site list by pulling down the Use Site menu for either site

1 or site 2. Pressing enter or clicking on the calculate button will calculate and display the distance between the two locations, the beam heading (or azimuth) from site 1 to site 2, and the Maidenhead Grid Locator for each location. Useful for pointing beam antennas used for HF radio work.

Once both desired sites have been identified, selecting the MUF option will plot a 24 hour chart of the Maximum Usable Frequency (MUF). This is useful for determining the optimal time of day and frequency for long distance (skip) communications between 2 locations. You are asked to enter either the solar flux or sunspot number (obtainable from WWV on 5, 10,15, or 20 MHz at 18 minutes past the hour) and the date.

Similarly, the Band Openings option lists the MUF from site 1 to 24 selected locations around the world for the selected date and time. This is useful if you want to know, for example, “where is 15 meters open to right now”? The list may be sorted by frequency by selecting the appropriate check box. The 24 sites cannot be changed, but are selected to give representative coverage around the globe.

Radio Horizon - Opens a window which will calculate the maximum line-of-sight distance between two locations. Enter the antenna height for each site, then press enter or click on the calculate button to calculate and display the maximum line-of-sight distance between the two locations. Distance to the horizon can be calculated by setting site 2 elevation to 0. If the elevation above sea level is significantly different at the two sites, this should be added to the antenna height for **both** sites. This is useful for determining expected range on VHF through optical frequencies. It of course does not take into account the effects of intervening terrain, antenna gain, or any unusual conditions (scattering, reflection or refraction).

Wavelengths - Opens a window which will calculate the basic wavelengths and harmonics for a given frequency. Enter the frequency in megahertz (MHz), then press enter or click on the calculate button to calculate and display the full, half, and quarter wavelengths for that frequency. Also displayed will be the first and second harmonics of the frequency and the frequency whose first harmonic is the entered frequency. The Antennas option provides instructions on how to build two of the simplest and most basic antennas

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- the dipole (useful and practical from about 1 to 30 MHz) and the ground plane (useful and practical from about 25 to 800 MHz). The wavelength calculations are useful for determining antenna element lengths, tuning transformer lengths, and harmonic relationships between frequencies.

Configure

New Site... - allows you to add a new site. You need to specify a name for the site, its position in latitude and longitude (can often be obtained from the blue pages in the phone book, the encyclopedia, maps, or the World Almanac), its elevation above sea level, the number of hours difference from UTC (local time - UTC), and the minimum elevation angle at which the satellite is visible (0° is the horizon, 90° is directly overhead). Normally 0 will be fine for the elevation angle, but if you have surrounding mountains or buildings, you may want to enter another angle. Up to 20 sites are supported.

Edit or Delete Site - Allows you to change any information about a particular site or delete any site. A submenu will appear which you use to select the site you wish to change or delete. You must have at least one site at all times - SatTrak will not allow you to delete the last site.

Elements to Text... - Convert a SatTrak Elements file to TEXT. Allows the file to be viewed and changed by any word processor or editor. Useful for adding, removing, or updating satellite orbital elements. Follow the formats listed in the Appendices for orbital elements.

NASA to Keplerian... - Convert a text file containing NASA format elements to Keplerian format. Note that this only converts the file, SatTrak does not read the converted elements in. To do this, after converting, you will need to quit SatTrak, move the converted file into the active system folder, and make sure it is named "SatTrak Elements". Now restart SatTrak and the new elements will be read in.

Use Other Elements... - Allows you to switch

to an orbital elements other than the default (found in the system folder).

Update Mode Info - Allows you to add, change, or delete information about the operational mode of up to 20 satellites. Some satellites, the OSCAR's for example, switch operating modes as they orbit. These parameters are published by AMSAT and QST. If mode information has been stored for the selected satellite, this information will be calculated and displayed on the appropriate plots.

Preferences... - Sets up your personal preferences for information to be contained in the output and other windows of SatTrak. Checked items will be contained in the resulting orbit plots. The items are:

- Azimuth - Azimuth of the selected satellite relative to the selected site. 0° is north, 90° east, 180° south, 270° west. This could also be called the heading or beam heading.
- Elevation - elevation angle of the satellite above the horizon. 0° is on the horizon, 90° is straight up, -90° is straight down.
- Doppler - for the specified frequency, calculate the doppler shift for the satellite. Due to the motion of the satellite relative to the site, the received frequency will be shifted from the transmitter frequency by this amount.
- Range - output range (distance) to the satellite from the site and the height of the satellite.
 - Latitude/Longitude - the point on the earth directly under the satellite.
- Phase - the "phase" of the satellite.
- Eclipsed - the satellite is in the earth's shadow.
- Apogee - if the satellite is in a highly elliptical orbit, prints when the satellite

reaches apogee.

- Flip - prints the Azimuth and Elevation in inverted format
- Mode - operational mode of the satellite (e.g. OSCAR's).
- Local Δ from UTC - the difference in hours from where the Mac is located and UTC. Negative for west longitudes (the continental US is -5 (EST) to -8 (PST) hours), positive for East longitudes.
- Units (Metric or English) - Selects which types of units will be used for all input and output - metric (meters and kilometers) or English (feet and miles).
- Time (Local or UTC) - Selects which time and date will be used for all input and output - local or UTC (Universal Coordinated Time, also known as GMT or Zulu). The conversion is done based on the UTC conversion you provide for that site (see the New Site... and Edit or Delete Site menus to change this). EST is -5 hours, PST is -8 hours. Satellite orbital elements are in UTC, so if you wish output in local time, this conversion factor *must* be correct.

Windows

Allows you to quickly bring any open window to the front.

Appendix A - NASA Orbital Element Format

NASA data for each satellite consists of three lines in the following format:

```

AAAAAAAAAAAA
1 NNNNNNU NNNNNAAA NNNNN.NNNNNNNNN +.NNNNNNNNN +NNNNNN-N +NNNNNN-N N
NNNNN
2 NNNNN NNN.NNNN NNN.NNNN NNNNNNNN NNN.NNNN NNN.NNNN
NN.NNNNNNNNNNNNNNN
    
```

Each line ends with a carriage return (CR).

Line 1 is a eleven-character satellite name. Lines 2 and 3 are the standard Two-Line Orbital Element Set Format identical to that used by NASA and NORAD. The format description is:

Line 2

Column	Description
01-01	Line Number of Element Data
03-07	Satellite Number
10-11	International Designator (Last two digits of launch year)
12-14	International Designator (Launch number of the year)
15-17	International Designator (Piece of launch)
19-20	Epoch Year (Last two digits of year)
21-32	Epoch (Julian Day and fractional portion of the day)
34-43	First Time Derivative of the Mean Motion or Ballistic Coefficient (Depending on ephemeris type)
45-52	Second Time Derivative of Mean Motion (decimal point assumed; blank if N/A)
54-61	BSTAR drag term if GP4 general perturbation theory was used. Otherwise, radiation pressure coefficient. (Decimal point assumed)
63-63	Ephemeris type
65-68	Element number
69-69	Check Sum (Modulo 10) (Letters, blanks, periods = 0; minus sign = 1; plus sign = 2)

Line 3

Column	Description
01-01	Line Number of Element Data
03-07	Satellite Number
09-16	Inclination [Degrees]
18-25	Right Ascension of the Ascending Node [Degrees]
27-33	Eccentricity (decimal point assumed)
35-42	Argument of Perigee [Degrees]
44-51	Mean Anomaly [Degrees]

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53-63 Mean Motion [Revs per day]
64-68 Revolution number at epoch [Revs]
69-69 Check Sum (Modulo 10)

All other columns are blank or fixed.

Example:

NOAA 6

1 11416U 86 50.28438588 0.00000140

67960-4 0 5293

2 11416 98.5105 69.3305 0012788 63.2828 296.9658

14.24899292346978

Note that the International Designator fields are usually blank, as issued in the NASA Prediction Bulletins.

Appendix B - Keplerian Orbital Element Format

Satellite: AAAAAAAAAA
Catalog number: NNNN
Epoch time: NNNNN.NNNNNN
Element set: NNNN
Inclination: NN.NNNNNNdeg
RA of node: NNN.NNNNNNdeg
Eccentricity: N.NNNNNN
Arg of perigee: NNN.NNNNNNdeg
Mean anomaly: NNN.NNNNNNdeg
Mean motion: NN.NNNNNNrev/day
Decay rate: N.NNNNNNe-NN rev/day²
Epoch rev: NNNN

Satellite: AAAAAAAAAA
Catalog number: NNNN
Epoch time: NNNNN.NNNNNN
.
.
.

Each line ends with a carriage return (CR).

Each satellite ends with a line with a single carriage return (CR).

Line headers must be exactly as shown above - the text followed immediately by a semicolon and a space, followed by the value.

NOTE: Some element sets have an alphanumeric (text) string for the Catalog Number or Element Set fields. Per the standard, SatTrak expects numeric (only - no alpha) values in these fields and will generate an error if non-numeric characters are included in these fields. Some Keplerian element sets also include a checksum line which is not accepted by SatTrak. If any of these problems are found in the format you obtain, you can use any text editor or word processor to correct them.