Satellite Contact Report Analysis & Prediction (SCRAP) Instruction Manual

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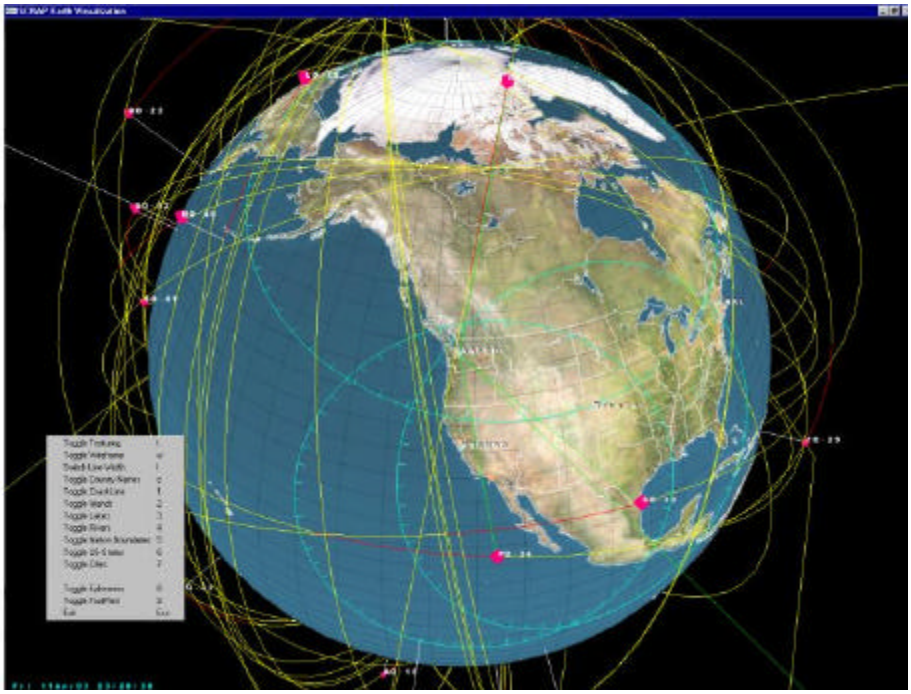
Intro to SCRAP

Satellite Contact Report Analysis & Prediction (SCRAP) is a tracking, report, analysis, prediction and 3-D real time display program. It tracks and predicts passes of satellites based on the geographical location of the ground station, the current date and time and Keplerian orbital data for the satellites of interest to the ground station. The software is capable of tracking over 2000 satellites real-time, as well as producing contact reports. In addition to the satellites, it provides ground labeling for over 260 countries and 2265 cities. The user is able to pick from 27 different map textures, and apply islands, lakes, rivers, US states, coastal lines and national boundaries lines.



The project started out as a challenge integrating satellite tracking technology into a 3-D display of the Earth. Additional features were later added for fun. I've invested many hours in the development and test already. The satellite tracking technology has proven to be quite a challenge to me, but the results are impressive. Therefore SCRAP is what amateur radio operators would consider a goldmine in satellite viewing and it's still free. It's available in the public domain as shareware.

SCRAP is similar to Analytic Graphics STK, Aerospace SOAP, Predict and InstantTrac software. Software was developed using Microsoft Visual C++, OpenGL and modified version of Glut DLL. The executable has been packaged in a zip file and placed in the public domain. It has been tested on Windows 95, 98, 2000 and ME.

Supported Computer Platforms

SCRAP is not for the underpowered computer. In order to propagate ephemeris for each of the satellites it displays and reports on, it performs millions of floating-point calculations every

second. Therefore, the minimum recommended platform is Windows 98 or better running a Pentium Processor 500 MHz or greater, 256 Mbytes RAM and a graphics accelerator card with OpenGL support. Of course it helps to have at least 1024x768 resolution.

For example, test results on a Windows 98 500 MHZ Pentium shows that it takes about 5 seconds to calculate 200 satellite vehicle positions and display the results. If your processor does not meet the minimum recommended horsepower it is suggested you should keep the maximum number of satellites at a minimum. This can be done at run-time via a command-line entry.

SCRAP does not access the Windows registry or place any hidden files on your system. It does have TCP/IP code for downloading TLE and APRS data from the Internet.

Installation Instructions

SCRAP is distributed using WinZip has all of the directory information and files needed for a basic startup of the program. To extract the files, use WinZip to create a folder/directory called "SCRAP" and unzip the contents. Create a startup icon next and place it wherever you find convenient on your hard drive.

Scrap creates several directories on your disk

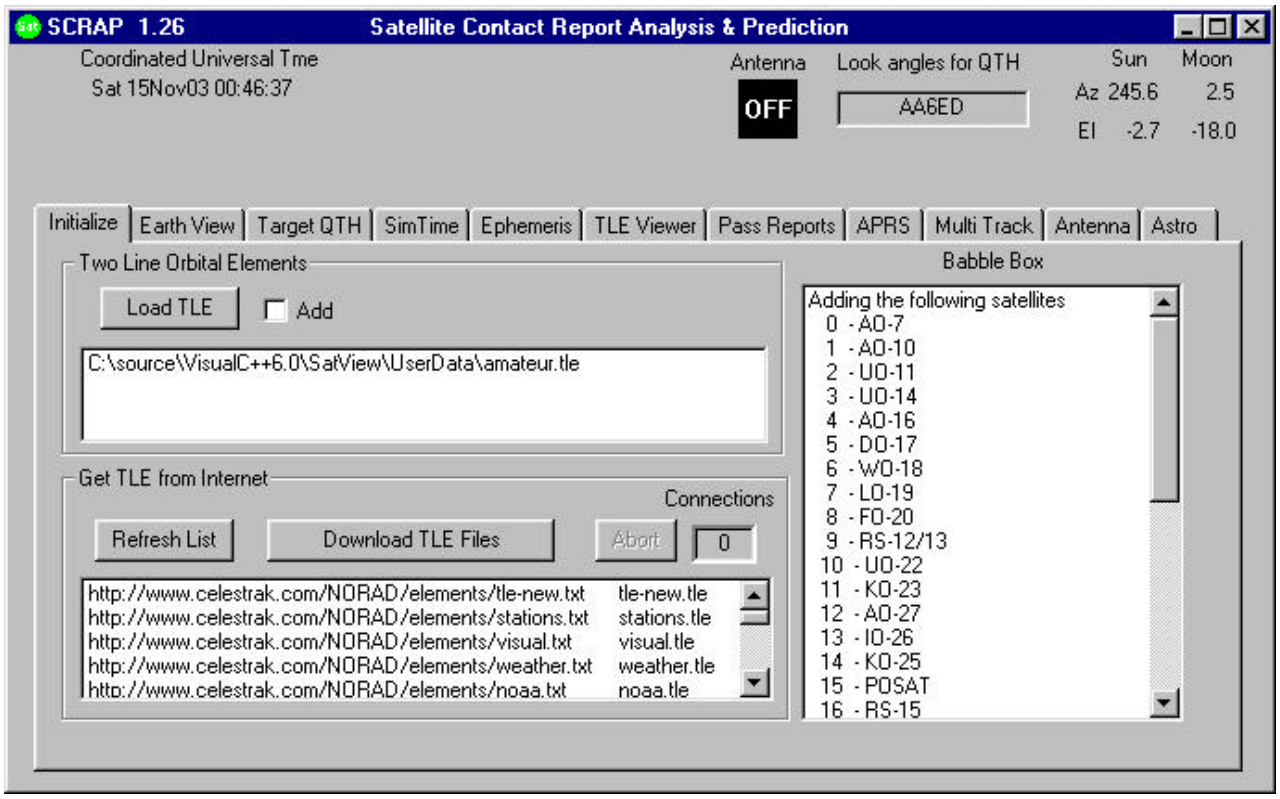
1. UserData – This is where you store the two line orbital elements and scrip files used by SCRAP. This manual will discuss these scrip files later
2. Images – SCRAP uses TGA images of the Earth for display on the 3-D display. If you wish to add additional textures of the Earth, this is where they go.
3. GlTexfont – Supporting fonts used by OpenGL and GLUT.
4. Vector Data – Vector data files used to draw boarders for countries, states, rivers and lakes. The basic binary data from the Pospeschil Micro World Data Bank II was generated using a trial-version of a program called Idrisi to convert the pairs of the '.vec' and 'dvc' files into '.vct' and '.vdc' (these are also binary files).

The display is organized into panels as shown in the picture below, thus allowing the user to control SCRAP's features. In summary these functions are:

Initialize	Allows the user to load in the various TLE files, and to download new TLE files from the Internet
Earth View	Selection of viewpoint to include country, satellite, QTH, etc. and to select the Earth Orthographic projection overlay map, and display options
Target QTH	Select the QTH to be used for pass predictions and reports
Sim Time	Define a simulation and step time other than current UST time.
Ephemeris	Set the SGP propagation model and view the position and velocity of satellites
TLE Viewer	View the decoded TLE parameter in classic Orbital Elements.
Pass Reports	Produce predicted orbit pass reports, visible passes and solar illuminations.
APRS	Download APRS stations via Internet. Locations can be used for prediction and display.
Multi Track	Display current and upcoming passes in real time
Antenna	Future enhancement for Az/El rotor control. This option is still being developed.

The following sections will discuss in further detail each of these functions.

Initialization Page



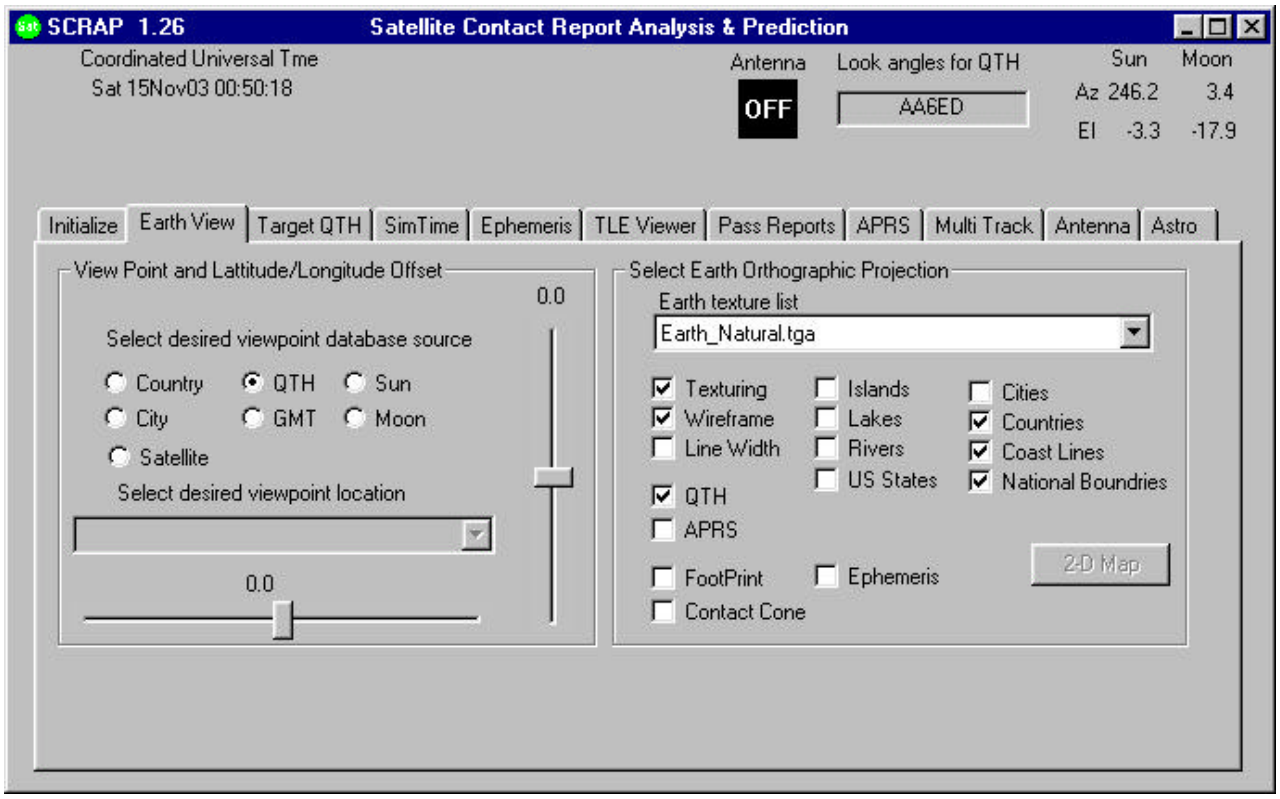
SCRAP opens with an initialization page as shown. The top left window is used to load Two Line Orbital Element files into the application. Pressing the "Load TLE" button brings up a file box allowing you to load any one of a number of satellite TLE files. Checking the "Add" button allows you to keep the existing selection and add additional satellites to the application.

SCRAP extracts valid NASA format 2-line Keplerian element (TLE) sets from the TLE input file, which may contain other text of various kinds. It removes the miscellaneous text commonly added by network e-mail and bulletin transmission. It can remove lines of text before, after, or between element sets, but not between the lines of a single element set. It can remove text on the same lines as the element sets, before or after the element sets, provided that the three lines of the element set all begin in the same column.

In addition, SCRAP allows you to add additional TLE sets from additional files to the existing set. Keep in mind that it does not check for redundant satellites in the batch.

Pressing "Refresh List" loads a scrip file into the buffer, at which time you can download the latest TLE data from the Internet. You can this text file called "Internet.lst" in the UserData directory and add or delete scripted items. Simply input the URL followed by an output file name on each line.

Earth View

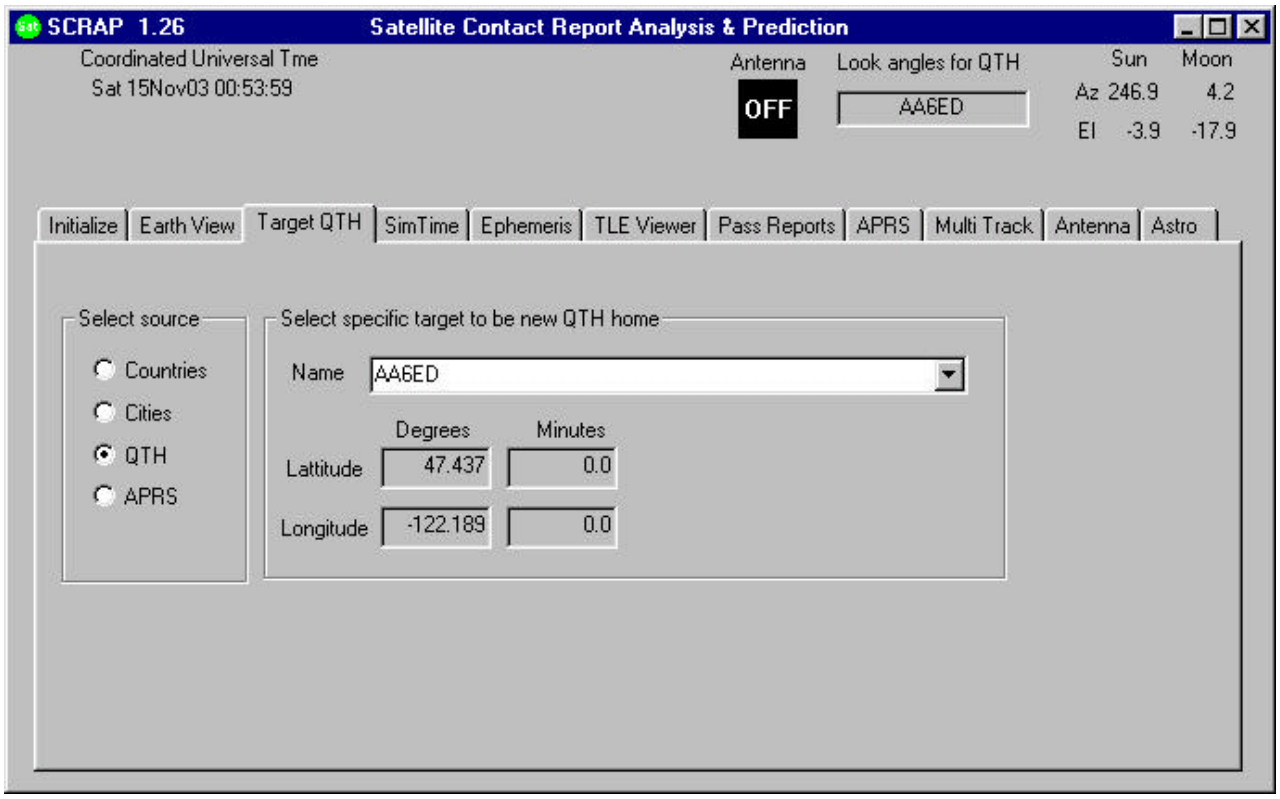


From the Earth View panel you can select the Earth orthographic projection of your choice. Your selection is then loaded into SCRAP and the Earth is displayed in it's own window. On slower computers this may take several seconds. The check boxes allow you to select display attributes on the Earth display. The View Point and Latitude/Longitude Offset allows you to select from a number of options for choosing your viewpoint. If you select a satellite, you are positioned above the satellite and the Earth rotates under your location.

The Earth-Simulation 3-D model was written by Ohad Eder Pressman in 2001 and placed in the public domain. The program is based on a large sphere, with a selected Earth map texture overlaid on the surface. You can rotate the Earth, zoom-in, etc. using the mouse and control key. Map textures of the Earth can be changed at any time during the run.

The GLUT extension to OpenGL is required for the 3-D display window controls. Since multiple processing threads are used for ephemeris prediction and display control, a modified version is provided that is SCRAP friendly. GLUT source code is in the public domain.

Target QTH

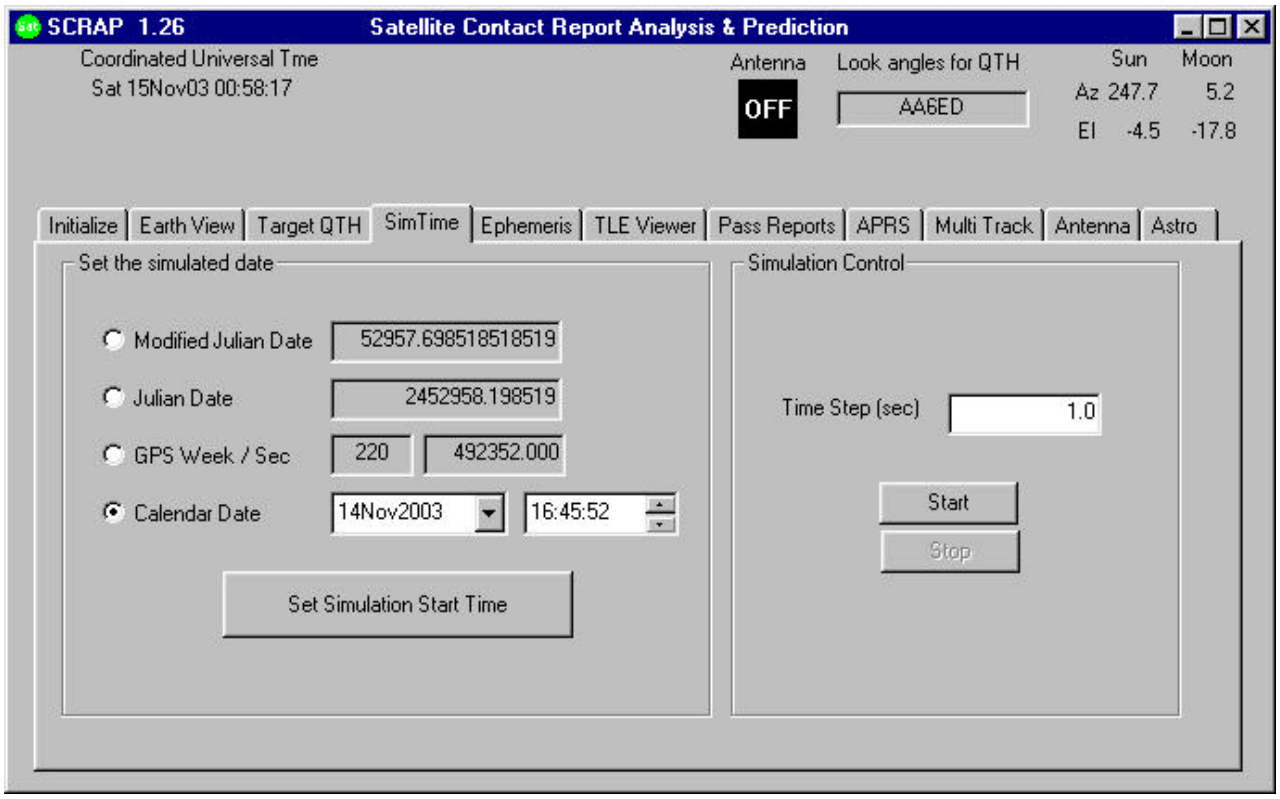


The original PREDICT tool performed all of its predictions based on a user input QTH, I've modified it so that the user can specify multiple QTH locations. This panel allows you to change the default QTH location to any city, country or QTH of your choice. The QTH control file stored in "UserData' is called qth.lst and has the format of callsign, longitude, latitude, elevation and GMT offset in hours.

I've added the capability for the user to assign any country, city, or APRS station to be the new QTH. You can easily move from location to location to predict and display satellite contacts for any location. The Target QTH display allows you to select various QTH locations to be displayed on the Earth's surface. You can select from predefined country or city data, a QTH file where you define your specific locations, or download APRS data from the Internet and use that location. The selected QTH is then used for creating pass prediction reports, the real-time Multi-Track display and for antenna rotor control.

SCRAP provides ground labeling for over 260 countries and 2265 Cities. In addition, the user is able to pick from 27 different map textures, apply island, lake, rivers, US states, coastal lines and national boundaries linesNote: If you activate the antenna rotor control, you are not allowed to change the QTH. This was done to prevent you from selecting a new QTH during a contact, thus forcing the antenna to slew from the current contact.

Simulated Time

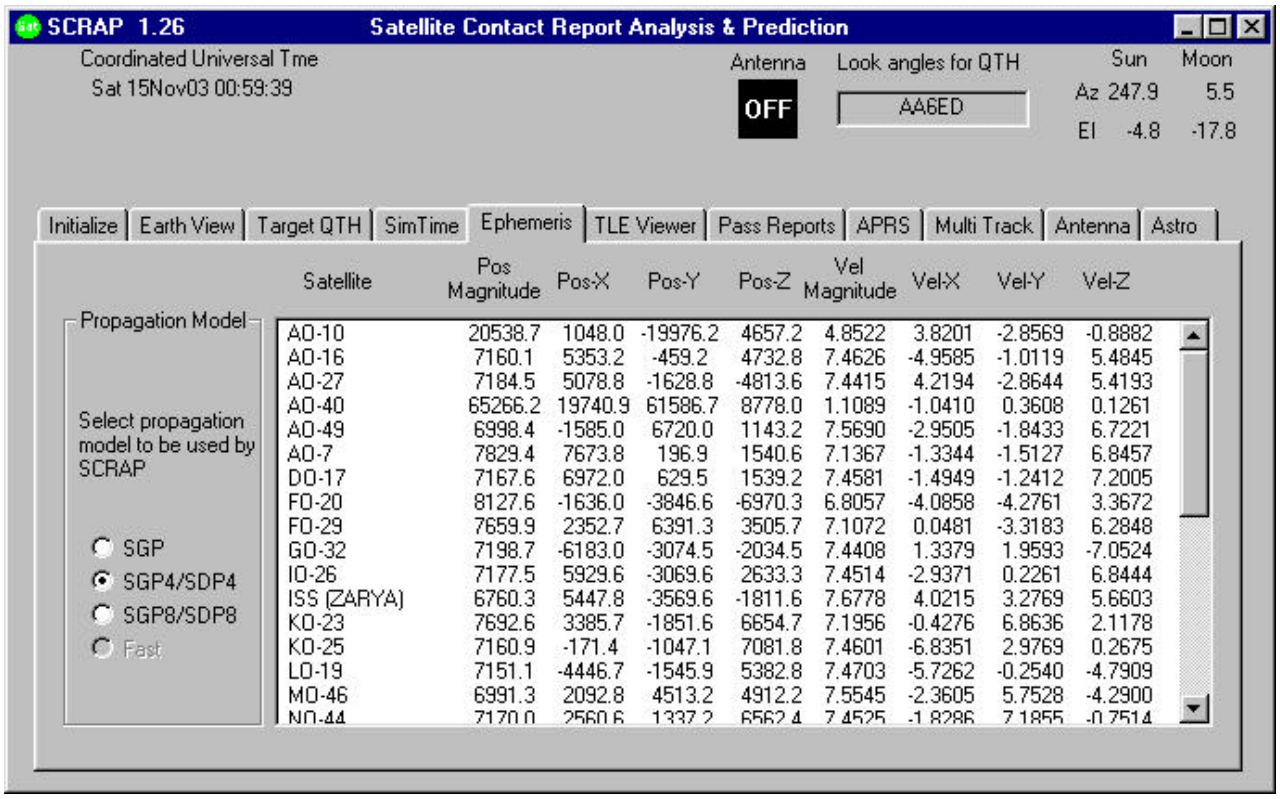


No tracking program is complete unless you can input any date time condition and set a fast forward or backwards time step. This panel allows you speed up reality.

The ability to control simulated time is provided to allow you to fast forward the simulation to get a perspective in fast motion of what the satellites are doing. You can also set a negative step time and run the simulation in reverse. The various time formats were provided for flexibility in setting up the simulation. All displayed times are in UST (GMT), but the user has the option of specifying times in GPS, MJD, JD or calendar formats.

Keep in mind that all times are in UST (GMT)

Ephemeris Propagation Model



The main ephemeris engine is Dr. T. Kelso's Pascal's SGP, SGP4, SGP8, SDP4 and SDP8 satellite ephemeris propagation routines. These models were borrowed from SPACETRACK REPORT NO. 3, Models for Propagation of NORAD Element Sets, Felix R. Hoots, Ronald L. Roehrich, December 1980.

This panel displays the current ephemeris vector data for position and velocity. In addition it allows you to switch ephemeris models in real-time. Normally you should never have to leave the SGP4/SDP4 model, but it's interesting to switch between the other models and observe the differences.

Borrowed from SPACETRACK REPORT NO. 3, Models for Propagation of NORAD Element Sets, Felix R. Hoots, Ronald L. Roehrich, December 1980.

Five mathematical models for prediction of satellite position and velocity are available. The first of these, SGP, was developed by Hilton & Kuhlman (1966) and is used for near-Earth satellites. This model uses a simplification of the work of Kozai (1959) for its gravitational model and it takes the drag effect on mean motion as linear in time. This assumption dictates a quadratic variation of mean anomaly with time. The drag effect on eccentricity is modeled in such a way that perigee height remains constant.

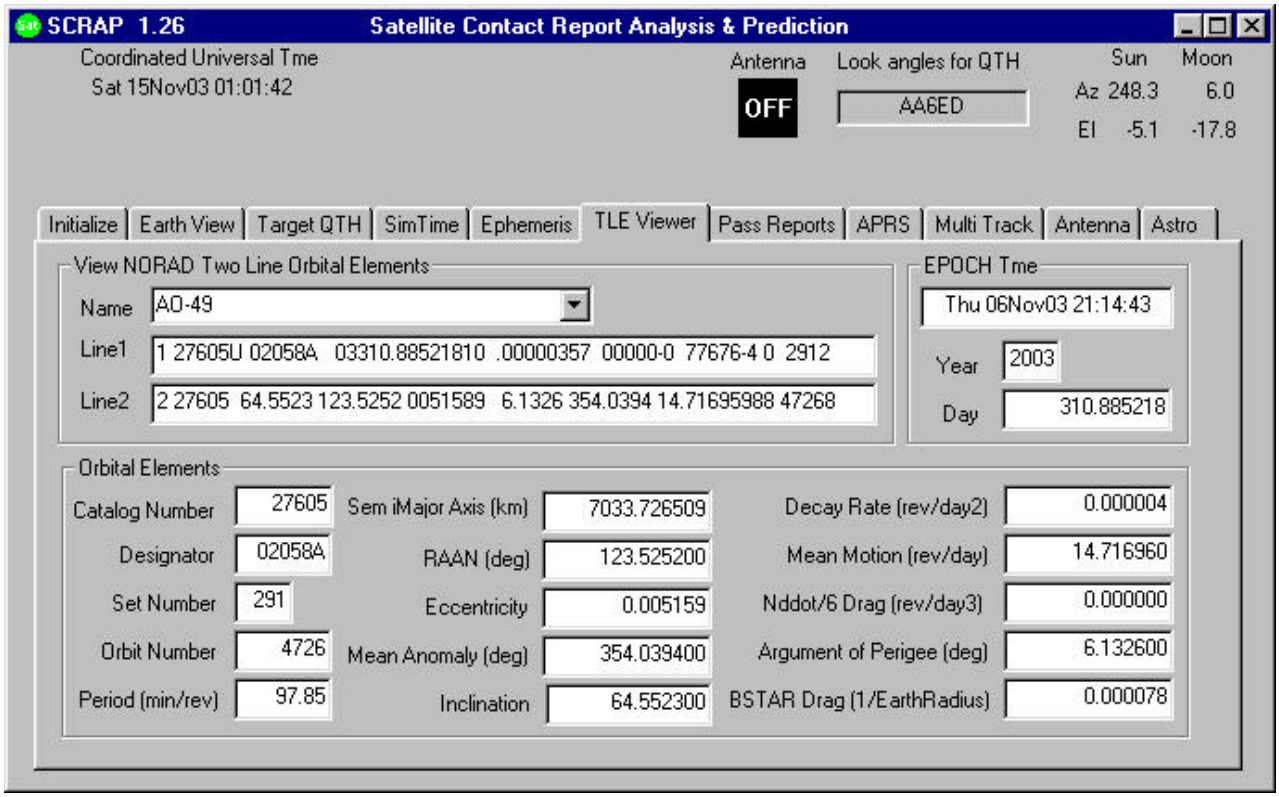
The second model, SGP4, was developed by Ken Cranford in 1970 (see Lane and Hoots 1979) and is used for near-Earth satellites. This model was obtained by simplification of the more extensive analytical theory of Lane and Cranford (1969) which uses the solution of Brouwer (1959) for its gravitational model and a power density function for its atmospheric model (see Lane, et al.

1962).

The next model, SDP4, is an extension of SGP4 to be used for deep-space satellites. The deep-space equations were developed by Hujsak (1979) and model the gravitational e?ects of the moon and sun as well as certain sectoral and tesseral Earth harmonics which are of particular importance for half-day and one-day period orbits.

The SGP8 model (see Hoots 1980) is used for near-Earth satellites and is obtained by simplification of an extensive analytical theory of Hoots (to appear) which uses the same gravitational and atmospheric models as Lane and Cranford did but integrates the di?erential equations in a much different manner.

Two Line Orbital Elements

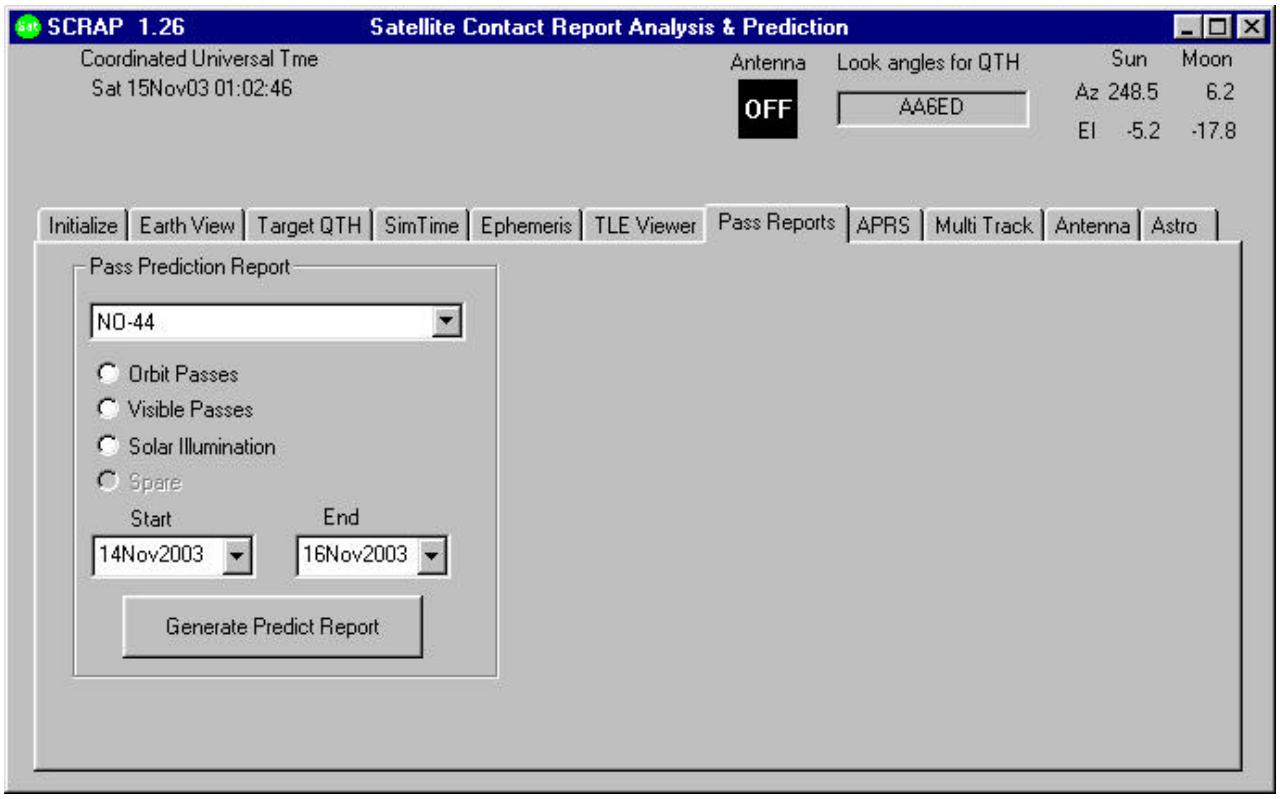


In order to give SCRAP the best performance, one should download the latest TLE files from the Internet using the "Initialize" panel. SCRAP extracts valid NASA format 2-line Keplerian element (TLE) sets from the TLE input file, which may contain other text of various kinds. It removes the miscellaneous text commonly added by network e-mail and bulletin transmission. It can remove lines of text before, after, or between element sets, but not between the lines of a single element set. It can remove text on the same lines as the element sets, before or after the element sets, provided that the three lines of the element set all begin in the same column.

In addition, SCRAP allows you to append additional TLE sets from input files to the existing set. Keep in mind that it does not check for redundant satellites in the load.

TLE data is downloaded using a pre-built script file. Pressing the download button initiates TCP/IP connections to the TLE source, and in a matter of a minute or so, you have downloaded the latest files set.

Satellite Pass Reports



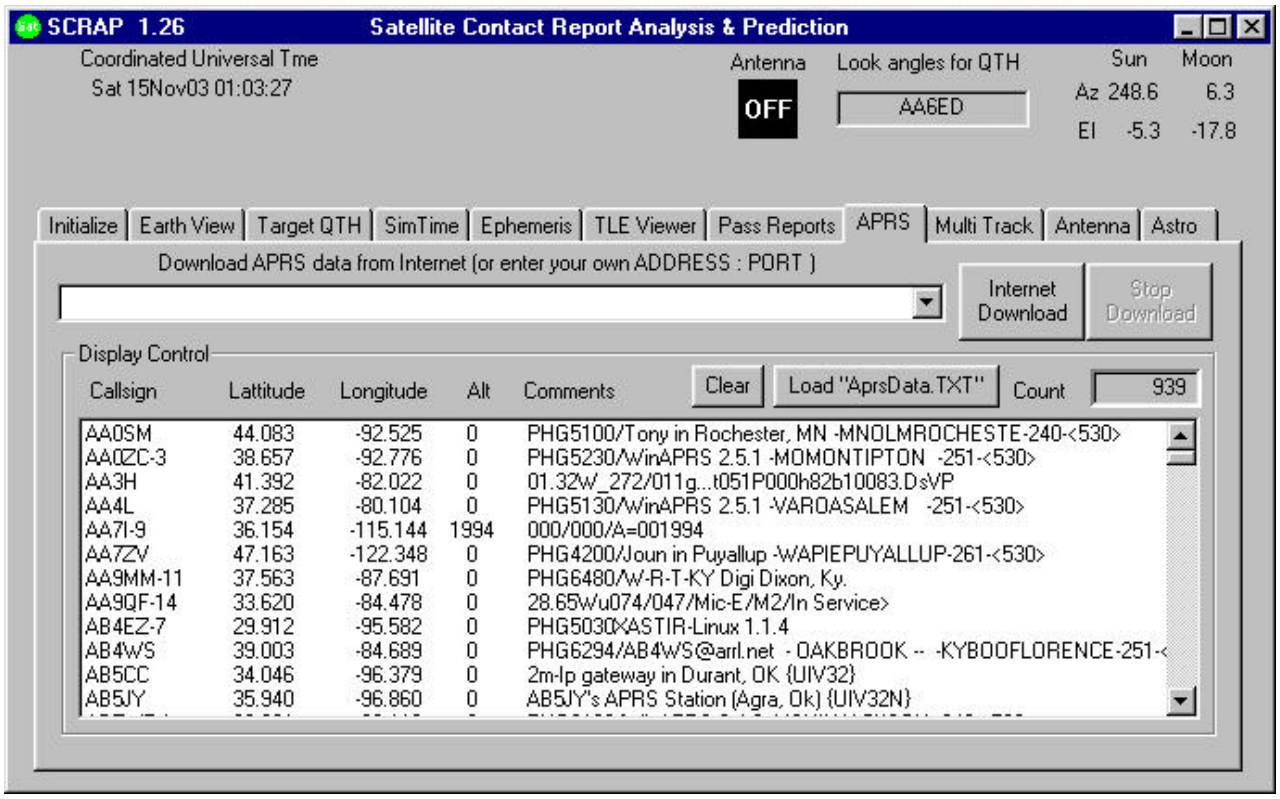
Satellite contacts in the program's database are calculated at a once/second rate. Separate windows are used to display current passes and upcoming passes. SCRAP also can create text-format reports of predicted passes. The satellite pass report options were originally developed and used in the PREDICT tool written by John A. Magliacane, KD2BD. John's report format was rewritten and integrated into SCRAP with some minor modifications.

Tracking data is also displayed for satellites in contact range. 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).

The Visible Passes report option displays the satellites in sunlight where the ground station is under the cover of darkness.

Solar illumination prediction report indicates how much sunlight a particular satellite will receive in a 24-hour period. 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.

Automatic Packet Reporting System



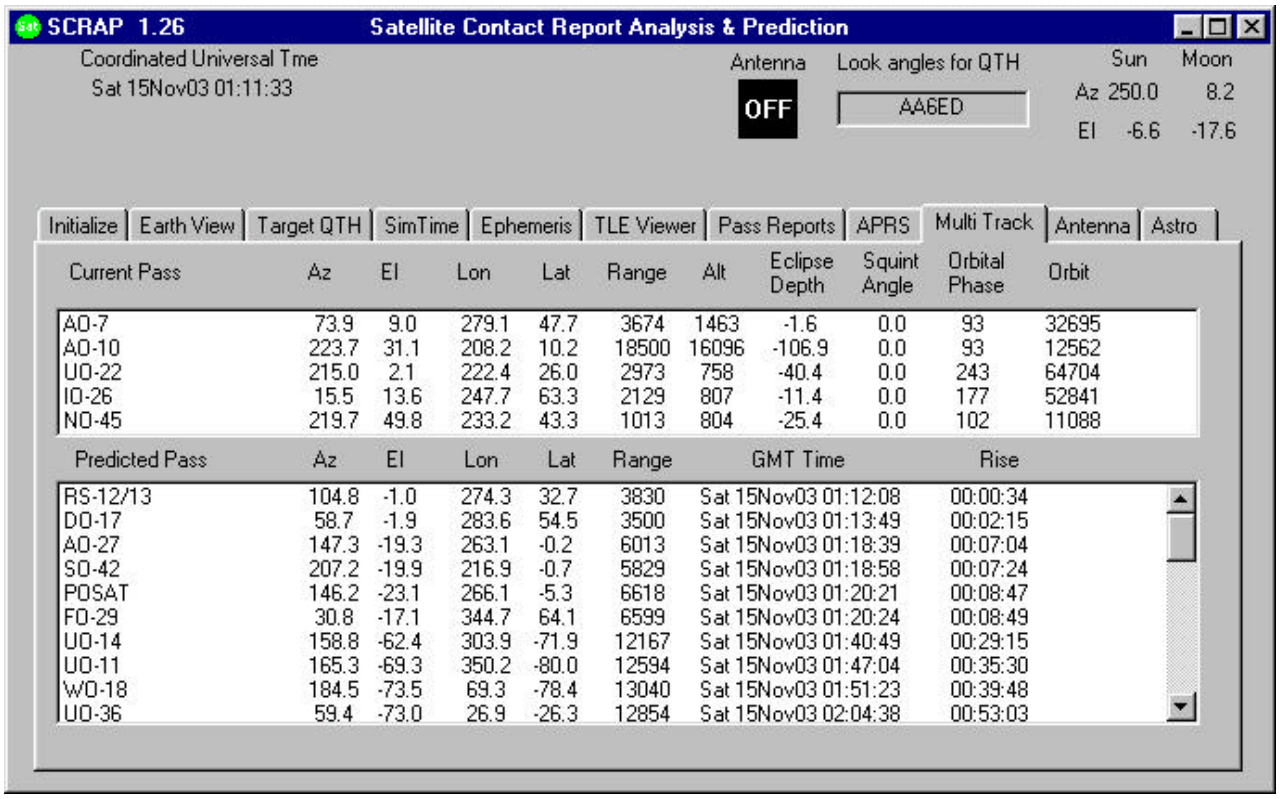
The project takes an interesting twist on this addition. The Automatic Position Reporting System (APRS) developed by Bob Bruninga, WB4APR, is used for tracking and digital communications with mobile GPS equipped stations with two-way radio (ref. http://www.aprs.org). SCRAP provides an Internet access that downloads APRS station information residing on multiple WEB servers as defined by the APRS Protocol published by the Tuscon Amateur Packet Radio Corporation.

The APRS protocol is not a very straightforward design, as multiple venders have added their own unique twists. SCRAP in its current form can only decode the simple latitude, longitude and altitude of most stations and attempts to display the broadcasted comments. Compressed APRS data fields are not supported.

To use the Internet download feature, select the desired WEB server and press “Internet Download”. If the counter does not increment, try another server, not all servers in my current list provide the proper protocol. Most servers will never disconnect, so the SCRAP design lets you determine when enough stations have been added to the list. You can go to multiple servers and add more stations as desired.

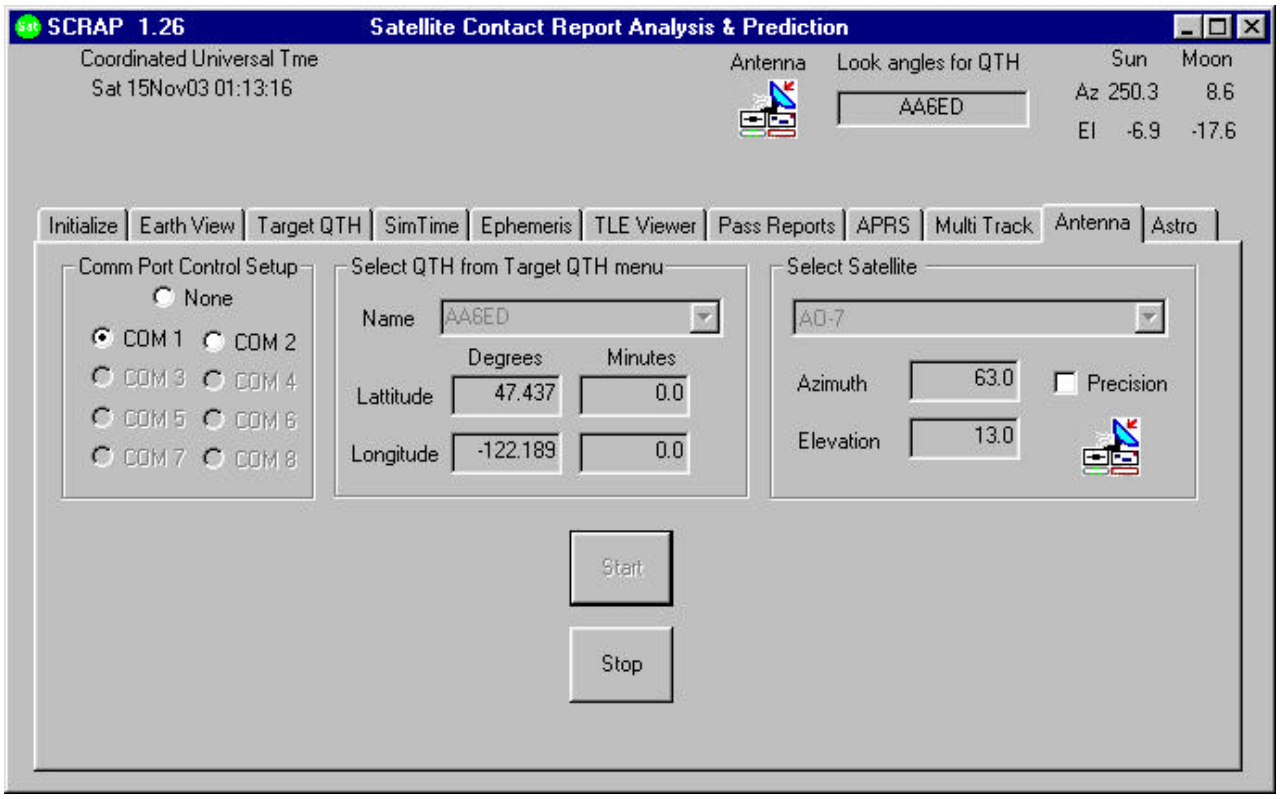
A file import option has been added that allows the user to import a text file dump of the Internet APRS servers. This is useful for displaying locations without the need for an Internet connection.

Multi-Track



This panel was inspired by the PREDICT program with some differences. The top window shows the current potential contacts. The bottom display shows the upcoming contacts. Probably the most useful number on this display is the time until rise of the next contact. Satellites are sorted by rise time.

Antenna

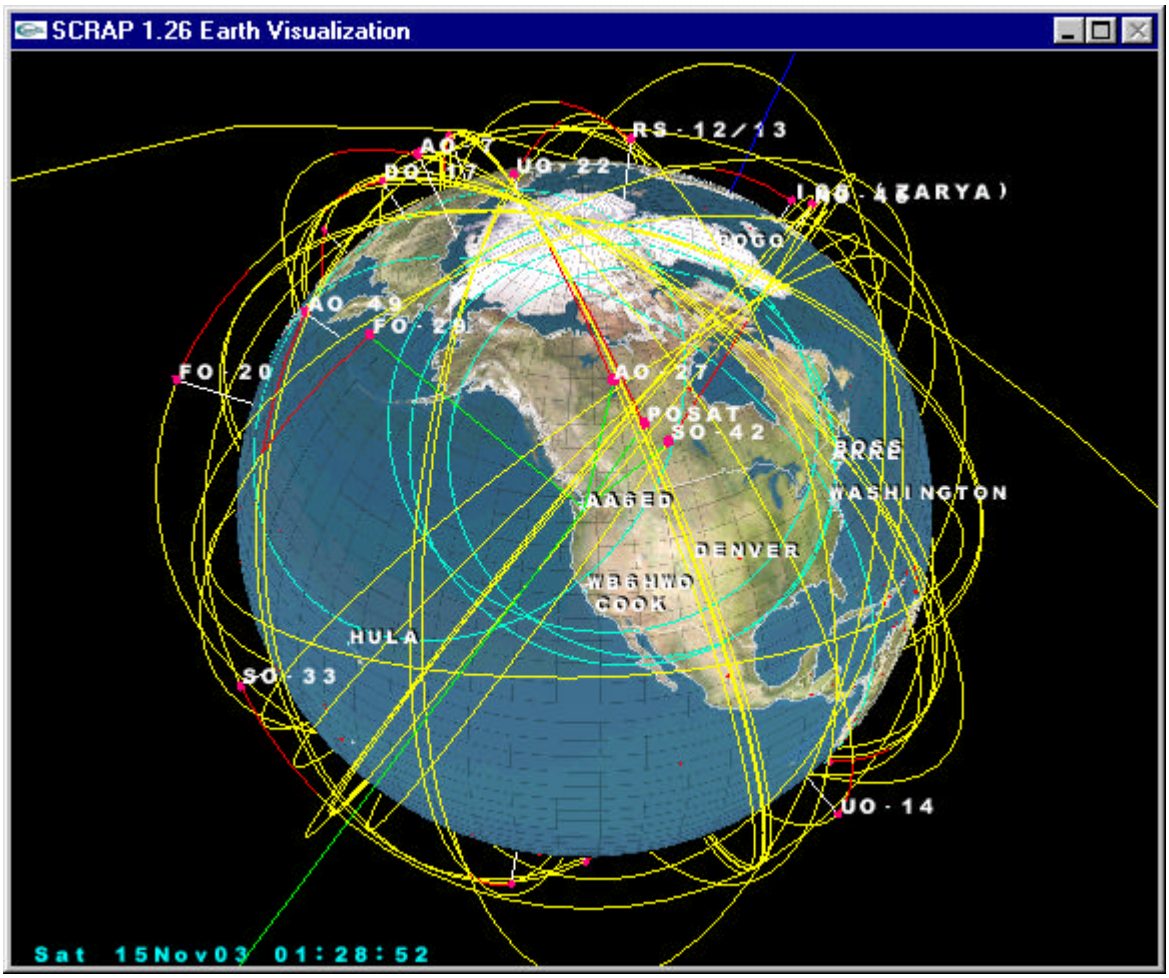


This antenna feature allows the user to control an azimuth-elevation rotor for a real-time contact. Elevation angles are suppressed until the angle rises above zero. The QTH is selected from the "Target QTH" panel, and once you start this display, you cannot change the QTH until you stop the action.

The precision function allows you to update the rotor with data less than one degree accuracy. Data is sent to the rotor once per second.

The Icon will change from an antenna (currently shown), OFF or LOS for loss of signal. The Icon is also displayed in the upper section.

Earth Image Control



Use the mouse and it's left-button to rotate earth. Hold down Ctrl before you hit the left mouse button to scale the earth. Right-Click the window to get the options menu. Note that options are controllable by keyboard too.

Numbers

Following are some basic numbers you might find interesting

NUM_SATELLITES	It's been said that SCRAP can handle up to 2000 satellites. At runtime the default is 500. If you wish to increase the number then include a command line parameter that defines the total number you wish to support, i.e. "c:\SCRAP\Scrap.exe 2000" for 2000 satellites. Just remember that the more satellites you add to the list, the slower the overall application runs.
NUM_COUNTRIES	There are 267 countries included in the database latitude/longitude.
NUM_CITIES	A total of 2267 cities are included in the database with latitude/longitude.
NUM_QTH	You can specify up to 50 unique QTH locations in the user-defined "QTH.lst" file. This file is stored in the UserData directory.
NUM_APRS	For some odd reason, included is space for up to 30,000 world-wide APRS stations in the dynamic database.

Public Domain Sources

1. PREDICT written by John A. Magliacane, KD2BD kd2bd@amsat.org , http://www.qsl.net/kd2bd/predict.html .
2. The C source code ported from NORAD's Spacetrack report #3, which included FORTRAN source for SGP, SGP4, SDP4, SGP8 and SDP8. According to a statement in that report, the document is free of copyrights and open to unlimited public distribution. Information found at http://www.projectpluto.com/sat_code.htm .
3. Two line orbital elements (TLE) are posted daily from Dr. TS. Kelso's CelesTrack website at http://www.celestrack.com/ . The OpenGL Utility Toolkit (GLUT) Programming Interface API Version 3 Mark J. Kilgard Silicon Graphics, Inc. November 13, 1996, downloaded at http://www.opengl.org/developers/documentation/glut/ .
5. NASAWASH NASA-Format Keplerian Element Set File Cleanup, updated 8 Mar 2002, Copyright 1995 Paul Williamson, KB5MU. All Rights Reserved, permission given for non-commercial purposes. Source and description found at http://www.mustbeart.com/software/nasawash.html .
6. 3-D Earth-Simulation, Ohad Eder Pressman, 2001. Source code creates the Earth sphere and map textures with rotation, zoom-in, etc. control, http://ohad.visual-i.com/exper/exper.htm#earth .
7. Equidistant Cylindrical maps from NASA/GSFC are copyright-free by Dave Pape, pape@evl.uic.edu . Maps can be found at http://www.evl.uic.edu/pape/data/Earth/ .
8. The GNU General Public license for software distribution can be found at http://www.gnu.org/copyleft/gpl.html .