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Version: 0.41

AMSAT
PACSAT Ground Station Manual

1 Introduction

Thank you for downloading the PACSAT Ground Station software.

PACSATground is experimental. We are sure it can be improved. Please provide feedback and suggestions by email to g0kla@arrl.net or by logging an issue at https://github.com/ac2cz/Falcon/issues

In theory this ground station will work with any Pacsat, but it was written specifically to support FalconSat-3 and Mir-Sat-1. In particular the support for telemetry collection is probably bespoke to those spacecraft.

1.1 License

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3 Getting Started

3.1 A bit about PacSats

FalconSat-3, Mir-Sat-1 and similar spacecraft run software that follows the PacSat protocols. This is a clever set of software routines that provide a delay tolerant network connection to the spacecraft. The protocols are split into two halves. The broadcast protocol and connected mode.

The broadcast protocol is used to receive data from the spacecraft. The files and data available on the spacecraft are broadcast as a directory listing. This means that all ground stations can listen and record the data.

Specific files are requested by transmitting a broadcast request to the spacecraft. The file is then broadcast in chunks of data and again all ground stations can receive it. Each ground station can then request the parts of the file that they missed. This makes it a very efficient way to communicate data to many stations and makes it possible to download the directory and files across fades and different passes of the spacecraft.

To upload files a ground station makes a dedicated connection to the spacecraft by logging in. The spacecraft then confirms space is available and provides the file number to use. The data is then uploaded. Again, this is very delay tolerant and picks up seamlessly across fades or passes.

You may think this is all very old and out of date, and perhaps using low speeds at 9600bps is, but the protocols form the basis of modern high speed, delay tolerant communications through spacecraft. It is a very robust solution for transmitting data around the world with no dependence on the telecoms infrastructure. I imagine a similar protocol will server us well when we exchange data with the moon or Mars.

If you want to learn more about the Pacsat Protocols then have a look at the reference documents at the bottom of this page: https://www.g0kla.com/pacsat/

A Pacsat produces a decent amount of telemetry. That telemetry is broadcast periodically and some also store telemetry in Whole Orbit Data (WOD) files on board. In fact, there is more data stored than a single AMSAT Operations ground station can download. We are asking for your help collecting telemetry. Any WOD files you collect and any broadcast telemetry you receive can be forwarded to the telemetry server. Partial files are just as helpful as complete files because we can reassemble them centrally. This means that receive only ground stations can contribute too.

3.2 Installing and running

There is no fancy installer for Pacsat Ground. You just unzip the distribution and put it in the directory of your choice.

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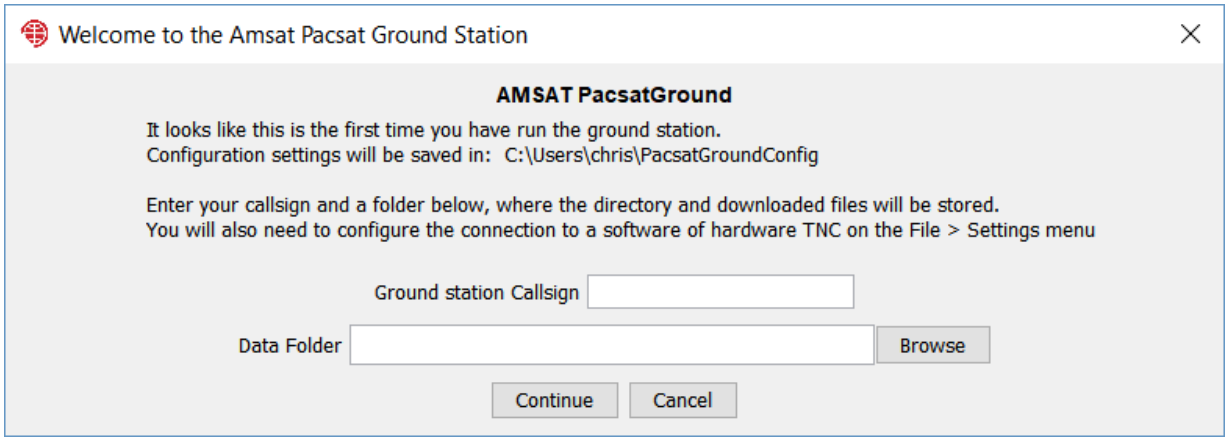
Once you have done that, to run on windows double click PacSatGround.exe. To run on Linux or MacOs you may be able to double click on the jar file or you can run the supplied start script, called PacSatGround. If that does not work then you can run from the command line. Make sure you are in the same directory as the program, then run with:
java -jar PacSatGround.jar

MacOs makes all of this quite difficult for non-technical users. You can run the program with the start script but you must first install the Java Development Kit (JDK). The Java Runtime (JRE) is not sufficient. If you have difficulty on MacOs then reach out and we will help.

When PACSATground starts you should have the Welcome screen shown below (unless you passed the data folder as a command line parameter). We recommend you choose a data folder that is different to the location of the program. This makes upgrades easier and avoids issues if the installation folder is not writable.

You need to a valid Amateur Radio callsign if you are going to transmit to the spacecraft. If you are a receive only ground station, then put something useful and unique as we use this name to keep track of who has contributed telemetry.



Pacsat Ground will write the configuration file into your home directory. This means it can find the configuration even if you change the data folder or move the installed program. For me on Windows that is c:\users\chris\PacsatGroundConfig\PacSatGround.properties

3.3 Troubleshooting Issues running PACSAT ground

Pacsat Ground will not start if you do not have java installed. You will get a message from the launcher telling you to download and install the latest version. Use Java version 8 (also called 1.8) or later. Right now my preferred installation is from AdoptJDK and you can find them here https://adoptopenjdk.net/, but any Java 8 or later version should work.

If you get an error message from Windows SmartScreen like the below, then click “More Info” and then “Run Anyway”. Windows gives this message for new or little known applications that have not established a reputation.

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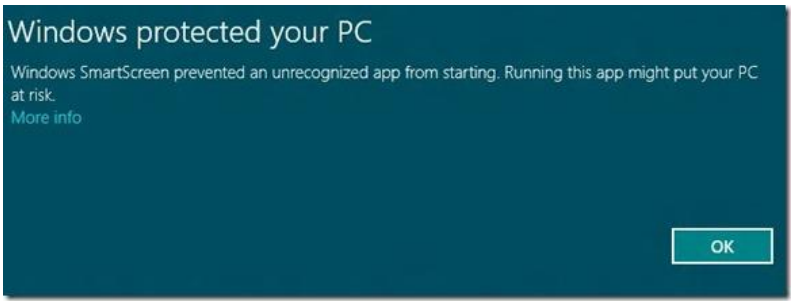

MacOS has similar security precautions.

If you are on Windows and the program complains that it is missing MSVCR100.dll or something similar to that, then you need to install the Microsoft Visual C++ redistributable. This is usually included by default in Windows, but sometimes it is not there:
For 32 bit Windows: http://www.microsoft.com/download/en/details.aspx?id=5555
For 64 bit Windows: http://www.microsoft.com/download/en/details.aspx?id=14632

If PacSatGound still won't start, then ask for help on the amsat-bb mailing list: https://www.amsat.org/amsat-new//tools/maillist/maillist.php or email g0kla@arrl.net.

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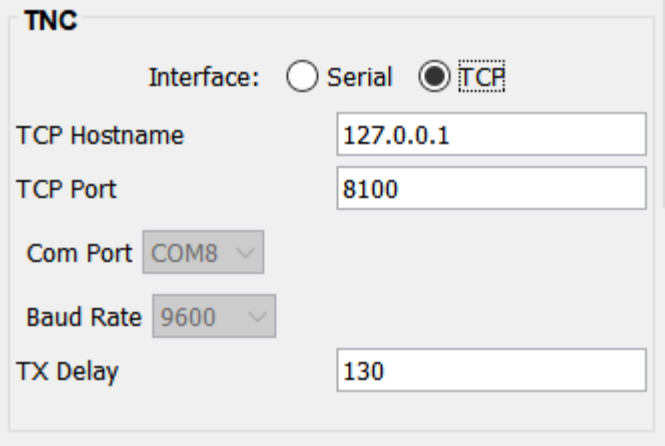
3.4 Setup

Pacsat ground is designed to have minimal setup. The parameters needed to connect to FalconSat-3 or Mir-Sat-2 are included in configuration files. You do not need to setup callsigns for the spacecraft. You do need to decide how you are connecting the computer to your radio and configure the connection. You have two options, a software TNC or a traditional hardware TNC.

3.4.1 Using a Software TNC

A software TNC such as hs_soundmodem is a good choice for most people. Instead of a serial cable data is passed to the Pacsat Groundstation through a TCP port. You need to download hs_soundmodem (hs for high speed). On the File > Settings screen make sure that TCP is selected in the TNC settings. The hostname should be 127.0.0.1 if you are running hs_soundmodem on the same machine. The default port is 8100, though you can change it in soundmodem.



In hs_soundmodem you choose FSK G3RUH 9600bp as the modem type on the Settings > Modems screen (or a different setting if the spacecraft you are using requires it). Configure it to be full duplex.

On the Settings > Devices screen select the sound card or cards that you will connect to your radio. Make sure the radio is in 9600bps packet mode. You can not take the radio's audio from the headphone or speaker jack. You must take the audio from a port that preserves the full bandwidth of the audio signal. The headphone and speaker jacks will be filtered to remove low and high frequency noise, so they are not suitable.

Under Server Setup, also on the Devices screen, make sure that KISS Server Port is enabled and has the same port number as the one you used in Pacsat Ground.

You will also need to arrange a way to key your radio to transmit. This is best acheived using a COM port. Select the COM port that you have used on the Devices screen.

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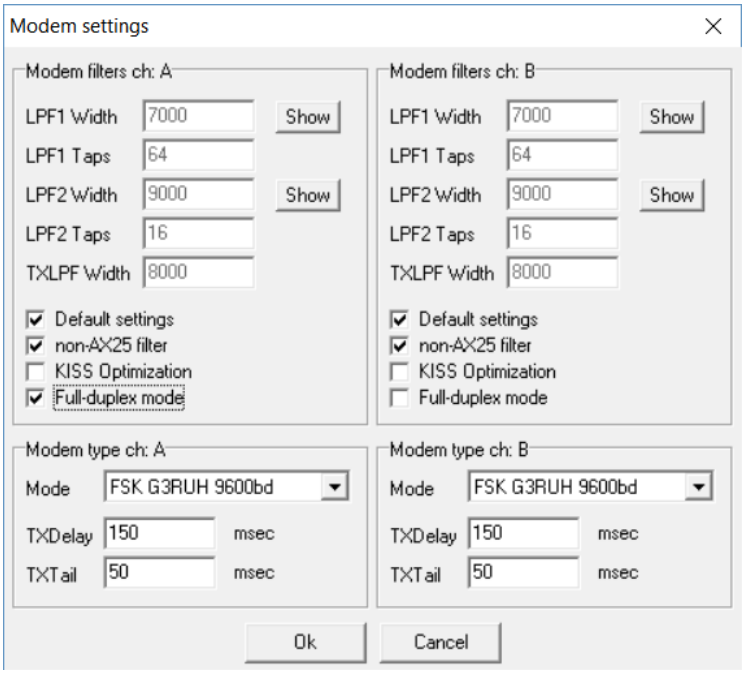
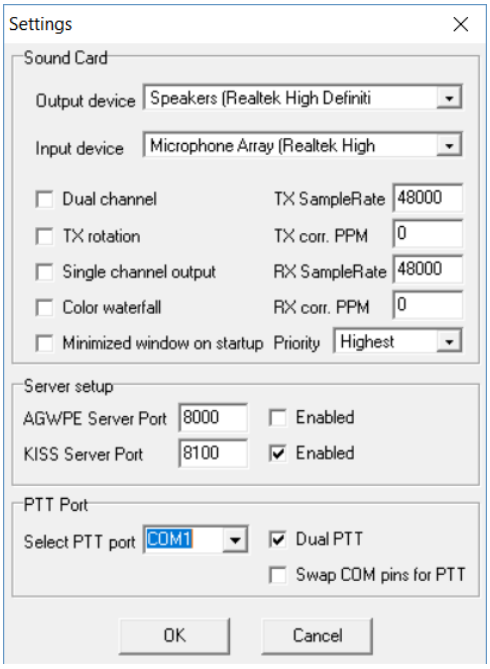
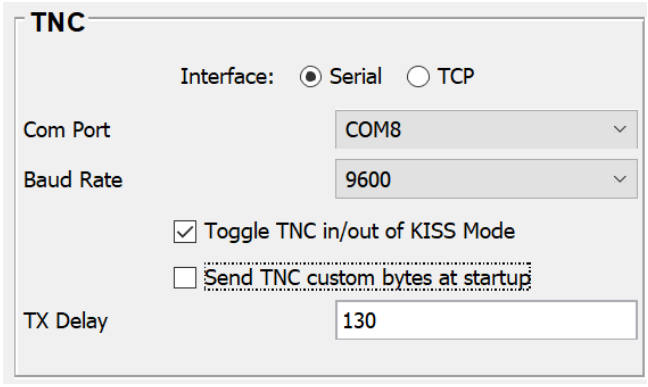




3.4.2 Using a Hardware TNC

If you have a hardware Terminal Node Controller (TNC) then you can use that instead of hs_soundmodem. On the PacsatGround File > Settings screen make sure that Serial is selected in the TNC section. Select the serial COM port that you are using to connect to the TNC. The baud rate here is the connection speed to the TNC and not the speed that the data is transmitted to the spacecraft.

You need to restart PacsatGround to connect to the TNC. PacsatGround tries to put the TNC into KISS mode and you should see the typical light sequence specified in your TNCs manual.



If the TNC does not go into KISS mode then it means it is not TNC2 compatible. Meaning sending the Sequence “KISS ON” followed by “RESTART” does not put it into KISS mode. You have two choices to address this.

Option 1 is to uncheck the setting “Toggle TNC in/out of KISS Mode”. Then exit the program. Connect to your TNC with a separate terminal program and issue the required incantation to put it into

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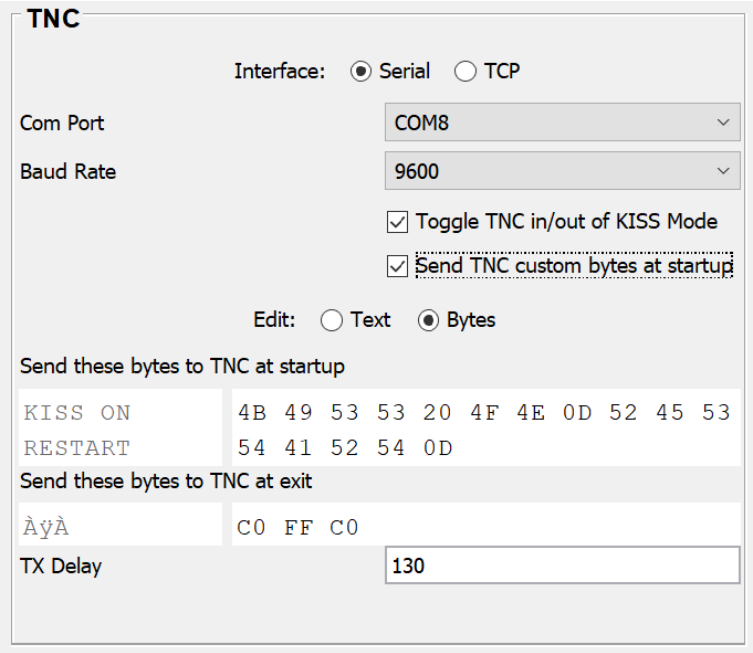
KISS mode. Then just leave it there. When you start the Pacsat ground station it will not try to put the TNC into KISS mode. It will send the KISS commands for Full Duplex and the TX Delay. At exit it will leave the TNC in KISS Mode.

If leaving the TNC in KISS mode is a pain, then Option 2 is to check the setting "Send TNC Custom bytes at statup". This shows additional fields to setup custom bytes. If they are not all visible then stretch the window.



The default bytes are shown above. You can either edit the bytes directly or edit the text. If you edit the bytes, then they are in hex and should have a space between each of them. Note that I have used 0D as the line termination in the default, which is a Carriage Return (CR), because that is what many TNCs expect. Some systems use 0A, which is a line feed (LF) and some use both. You will need to check in your TNC manual to see what bytes are required. If you hit Enter when in the Text section it will insert a Line Feed (0A). That may or may not be what you want.

Note that the ground station will still send the KISS commands for Full Duplex and for the TX Delay after the TNC is in KISS mode, so you do not need to enter bytes for those commands.

3.4.3 Initial Test

Is the TNC connected? If you press the "DIR" button at the top of the main window it will request a directory, even if the spacecraft has not been heard. You should see lights operate on your TNC and the radio should be keyed. RF should be transmitted. So make sure the antenna or a dummy load is connected! In a software TNC you will see the KISS bytes printed on the display.

Note that the Ground station may refuse the request and print this in the log area:

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```
Ignored DIR REQ: Wait until your current PB session has completed before
requesting another directory
```

That means that you have already been heard by the spacecraft and you should wait before sending another directory request. If you wait for a minute then the Downlink Wait timer will expire and you will be able to request again.

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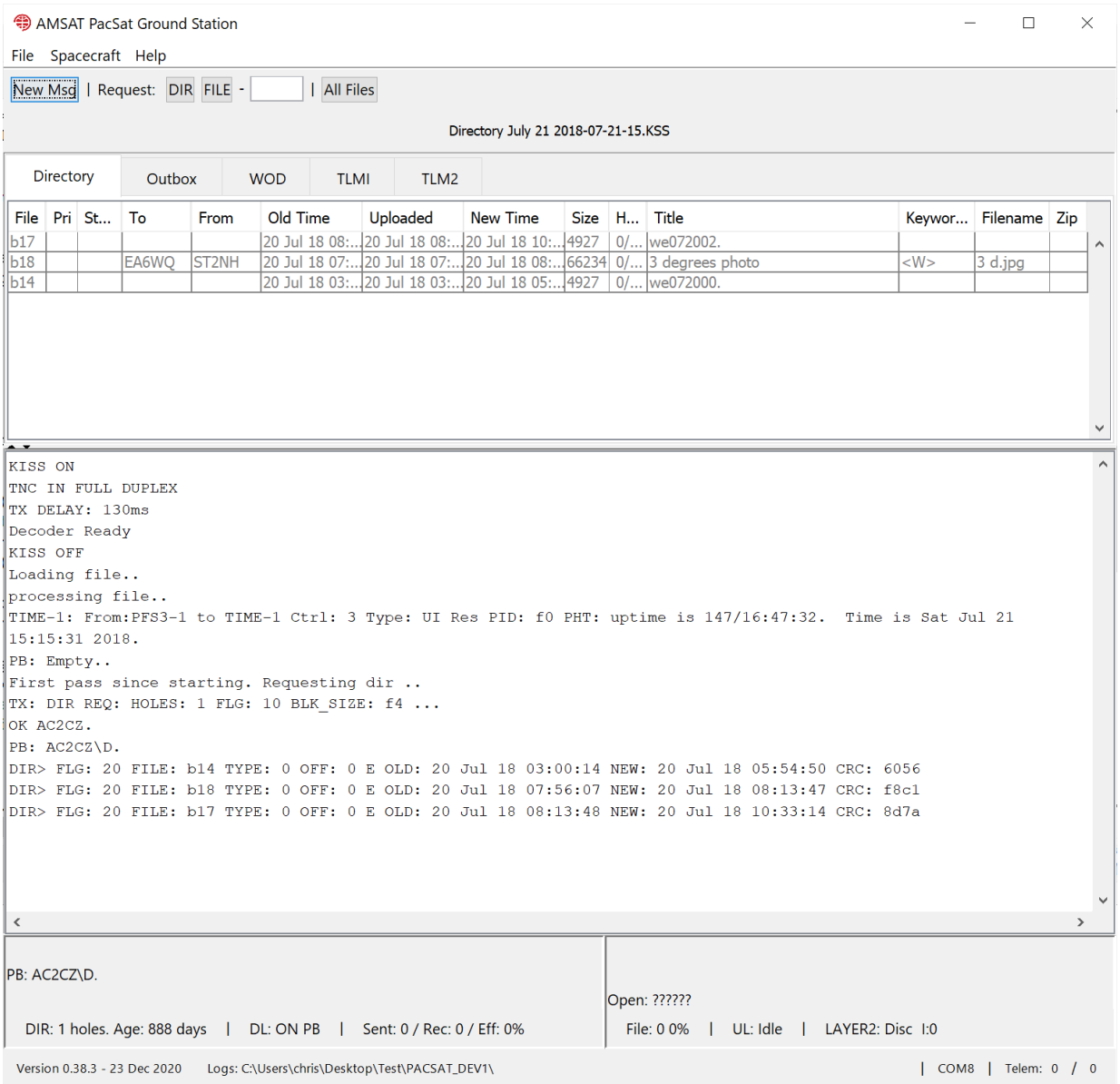
4 Live operation

4.1 First pass

When in Pacsat mode, the spacecraft is constantly transmitting, so as an initial test just listens for the spacecraft. 9600bps packet radio sounds like white noise, so it can be hard to tell if you are receiving the signal. The S meter may well move and the DCD light will come on when data is being heard. Like all spacecraft you will need to compensate for doppler by retuning the radio. I have my FT736R connected to SatPC32 for that purpose.

Let's look at a pass and talk about the display in the ground station:



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When we start the ground station it prints KISS ON, TNC IN FULL DUPLEX and TX DELAY: XXXms. It sends those KISS commands to the TNC. You can see these printed in the log area of the screen shot above. Ignore the words "Loading file.." and "processing file.." which show I replayed a KISS file to show this data.

In the absence of any requests the spacecraft transmits several things. First, we see the time on the spacecraft. The next message is the status of the "PB". The PB is a queue indicating who has requested Pacsat data to be Broadcast. If no one has requested anything you will see:

PB Empty ..

This indicates that no one is on the PB but that the PB is available for use.

Pacsat Ground then notes that this is the "First pass since starting.." and requests the directory. If you don't want PacsatGround to transmit (perhaps no transmitter is even connected) then you can disable it on the File > Settings screen by selecting "Inhibit Transmitter".

If the transmitter is enabled then the message transmitted to the spacecraft is shown, which in the screen shot above is a directory request for 1 hole:

TX: DIR REQ: HOLES: 1 FLG: 10 BLK_SIZE: f4 ...

(for an explanation of directory holes, see the Pacsat protocol reference documents here https://www.g0kla.com/pacsat/index.php, especially this document which explains how they work https://www.g0kla.com/pacsat/bdcastu2.txt):

We then get two responses:

OK AC2CZ.
PB: AC2CZ\D.

This shows that our transmission was heard and that we are now on the PB with a directory request. Note that the status of the PB is also shown in the bottom left of the window, together with the number of holes in the directory and its age, meaning the oldest file header that Pacsat Ground will request. You can adjust this age on the Spacecraft > FalconSat-3 screen.

While we are requesting the directory the spacecraft will transmit telemetry and other status messages, including the status of the uplink, if it has one. For example, if we see a message like:

Open ABCD:

This means that the uplink to the spacecraft is open and available for use. Currently FalconSat-3 allows uploads but Mir-Sat-1 does not.

There are 4 possible uplinks (A-D) but I think only A is available on FalconSat-3. Notice that the status of the uplink is shown in the bottom right of the window together with details of the uplink state

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machine and the layer 2 state machine. These are mostly to help me debug things, but if you are curious I can explain what it all means. Send me an email.

If the uplink is available and you have a file to upload, then Pacsat Ground will attempt to login. See the section on uploading files below.

4.2 All about the directory

The spacecraft has an onboard file system which stores Pacsat headers for each file. The files are split into two types: System files and User files. By default on the system files are hidden for FalconSat-3 as most people are interested in the user files. For Mir-Sat-1 only system files are available, so they are displayed by default. You can change which files are shown by pressing the button labeled "User Files" near the top of the screen. It will then say "All Files" and the System files will be shown mixed in with the user files. If you press it again them only the user files are shown.

We see a typical directory listing for user files below. If we have received the Pacsat file header for a file, but no other data, then it is in light grey. Once we receive some data the file is in black. You can see in the "Holes" column the number of holes that the specific file has and the percentage of bytes downloaded for that file. File holes can be of any size, so the number is not that meaningful and can rise and fall as different parts of the file are received. Eventually the holes will reach zero and the percentage downloaded reaches 100. The file will then be colored blue unless it is directly to you, then it is red.

Unread files are in bold. Read files are no longer in bold.

But you do not have to wait for a file to be fully downloaded before you try to read it. Often partial files can be opened and understood. Partial images will be displayed whenever that is possible. Large images from Mir-Sat-1 will be incrementally downloaded and the file window can be left open to monitor the progress.

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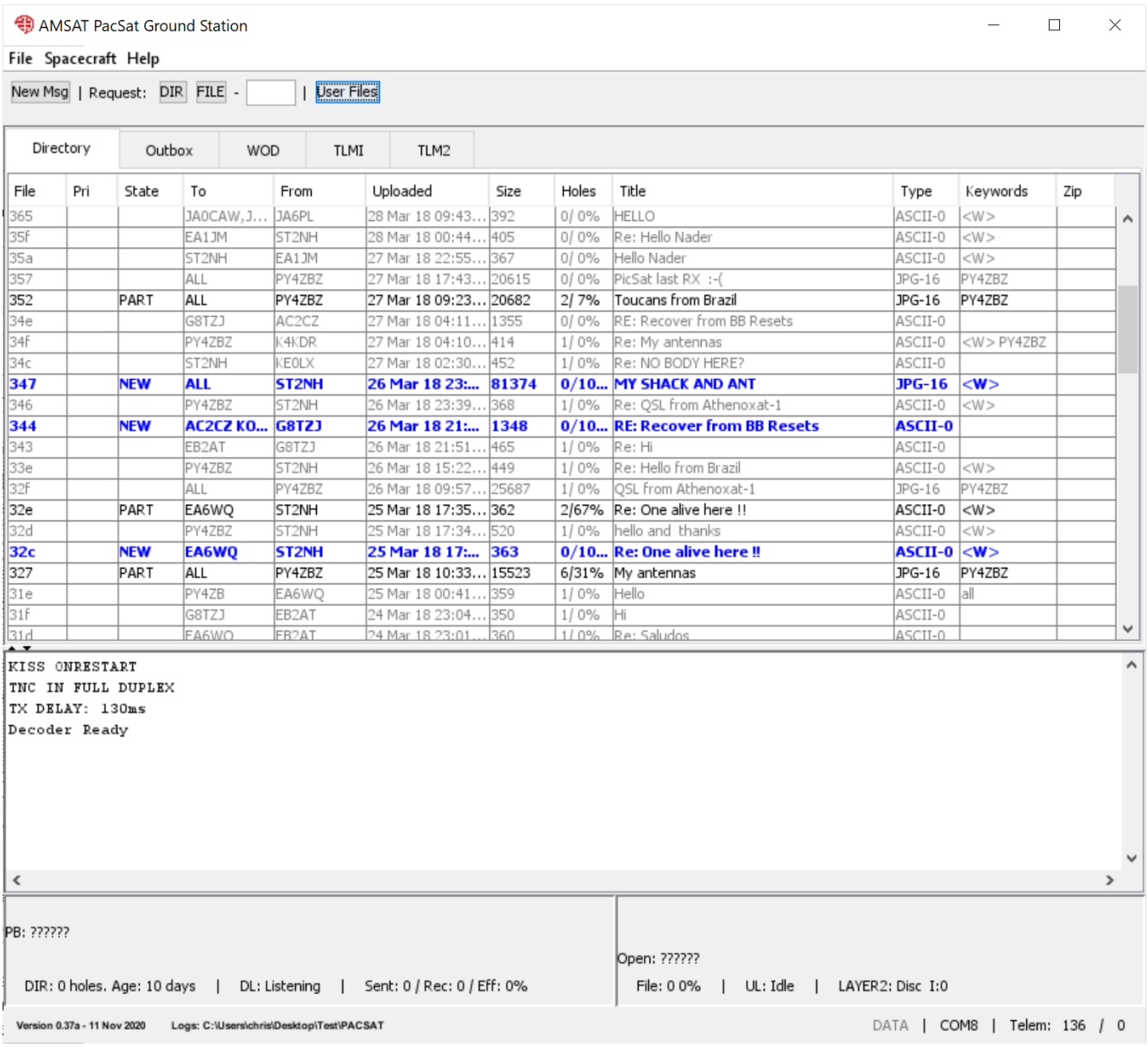

To mark a file for download, select it with the mouse or the arrow keys and then press one of the numeric keys from 1-4. This will give it a download priority, with 1 being the highest priority. You can also select 0 to clear the priority or N to prevent the file from being downloaded automatically, as discussed below in the section on Directory Selection Equations.

If you double click on a file then it opens in another window, as I did with the message “MY SHACK AND ANT” from Nader, ST2NH. You see the result below, a really nice image he uploaded.

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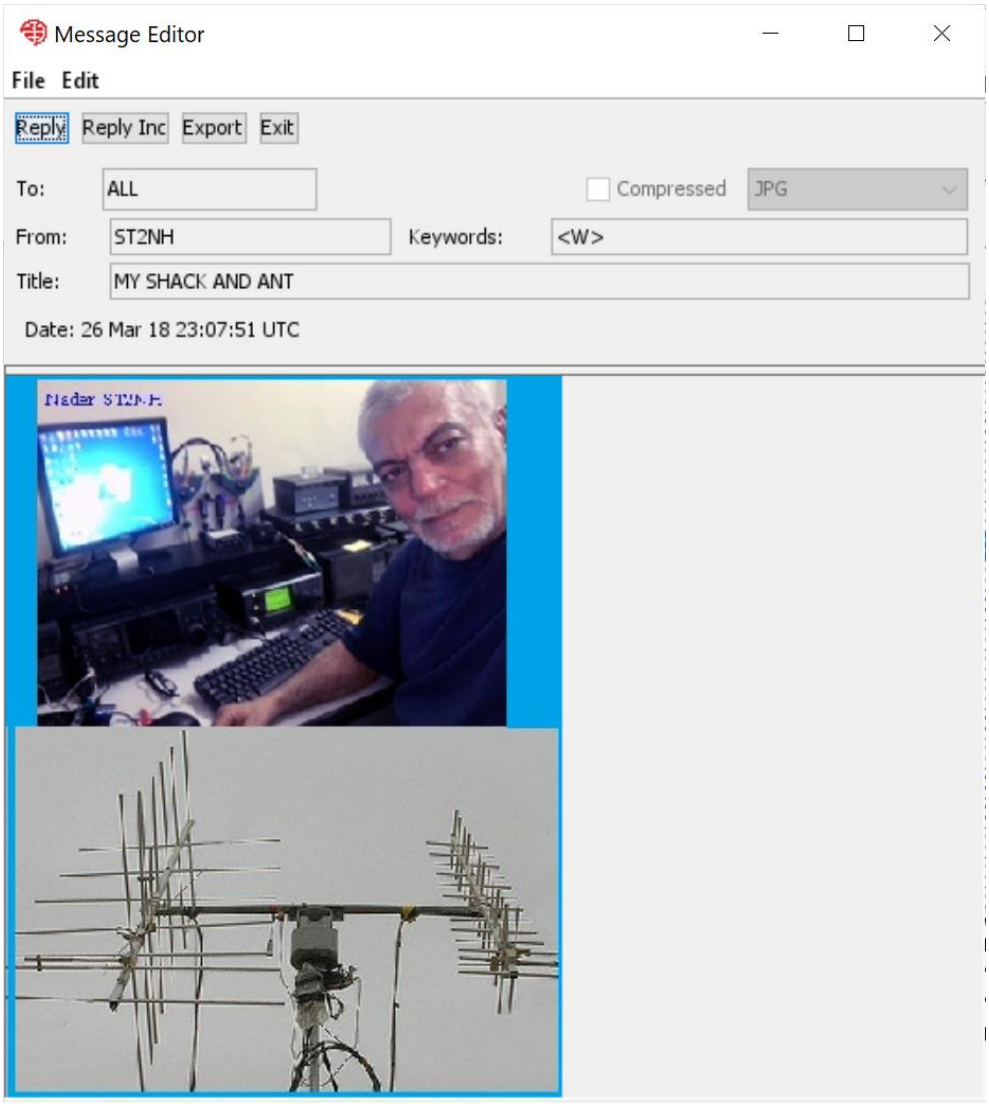

From here you can reply to the message if the spacecraft supports uploades. If it is a text-based message you can press "Reply Inc" to include the original message in your response.

4.3 Telemetry

We would like your help downloading telemetry from the spacecraft and then uploading it to the telemetry server. All you need to do is go to the File > Settings screen and complete some of the details. Fill in your locator or lat/long and make sure "Send Server Telemetry" is selected. Then any downloaded telemetry is forwarded to the server. Telemetry for FalconSat-3 is sent to AMSAT-NA and telemetry for Mir-Sat-1 will be warehoused at SatNogs.

This setting will automatically forward broadcast telemetry and any full or partial Whole Orbit Data Files received. If you are able to transmit to a spacecraft like FalconSat-3 you may want to ask for WOD files to be downloaded automatically using a Directory Selection Equation, as described below. Even if you don't manage to download complete files, any partial fragments are very helpful.

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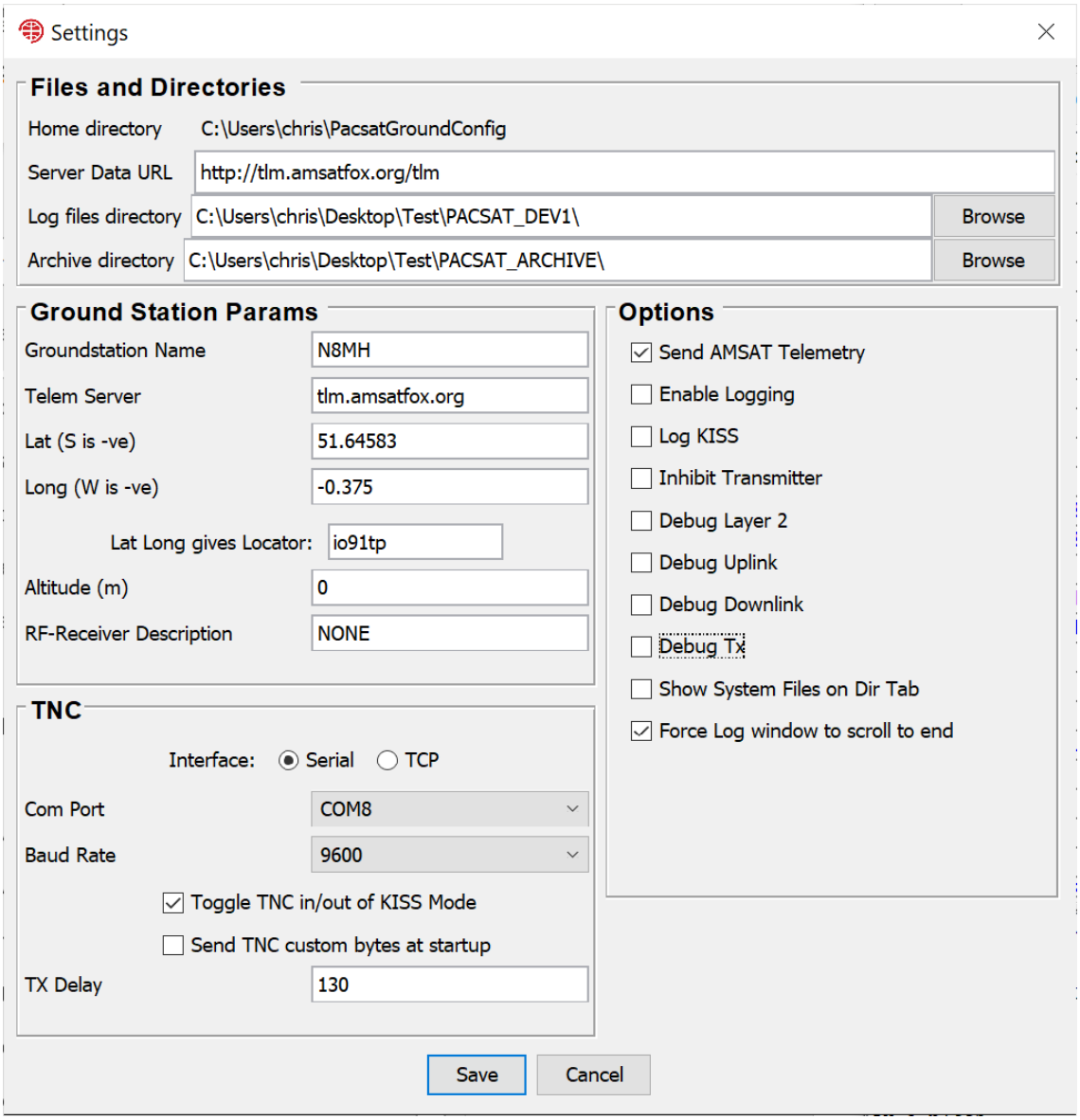

Downloaded telemetry is shown on the WOD, TLM and TLM2 tabs. If you are familiar with FoxTelem then you will recognize these screens. Like FoxTelem, if you click on a value a graph opens up and plots the data that you have collected.

For FalconSat-3 you can download the telemetry that everyone else has uploaded. Select File > Fetch Server Data. But be careful. You will get a warning that your existing log file data will be overwritten. This will only overwrite telemetry logs and won't impact your directory, your downloaded System Files or your uploads. If you don't want to overwrite, then switch to a new directory using File > Settings or create shortcuts to start PacsatGround with different directories passed in as a parameter. I have a shortcut called FS-3 Server that starts PacsatGround in a directory that only contains server data.

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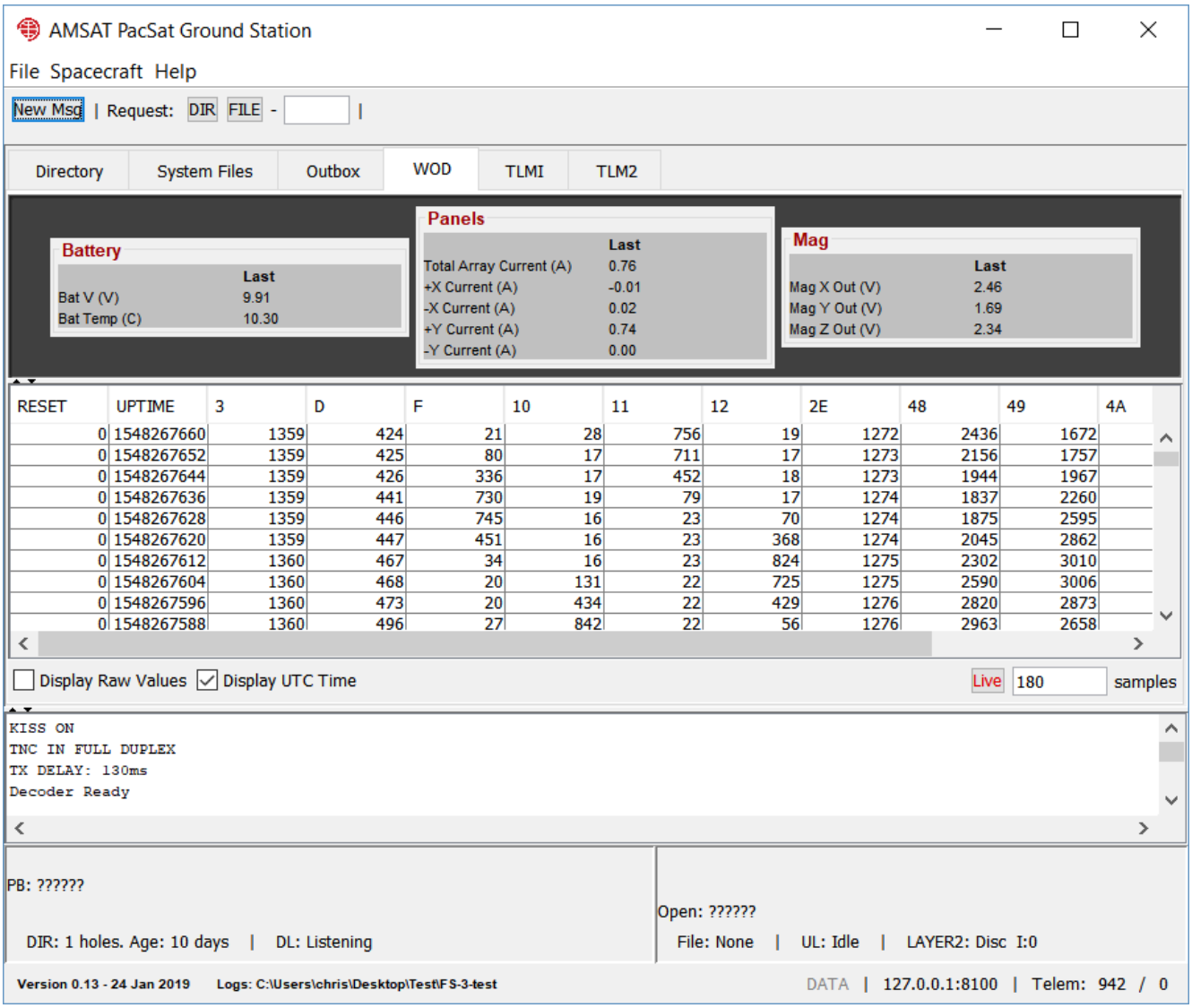

Below is a graph of Bat V from the Whole Orbit Data, showing the last 180 values. By default this is plotted against UTC. Unlike the Fox spacecraft, "Uptime" just shows the number of seconds since the Unix date epoch and not the uptime of the spacecraft.

You can use the "+" button in the top left to add other traces from the same data set. Saving to a file as CSV values is not yet working. Let me know if you need it.

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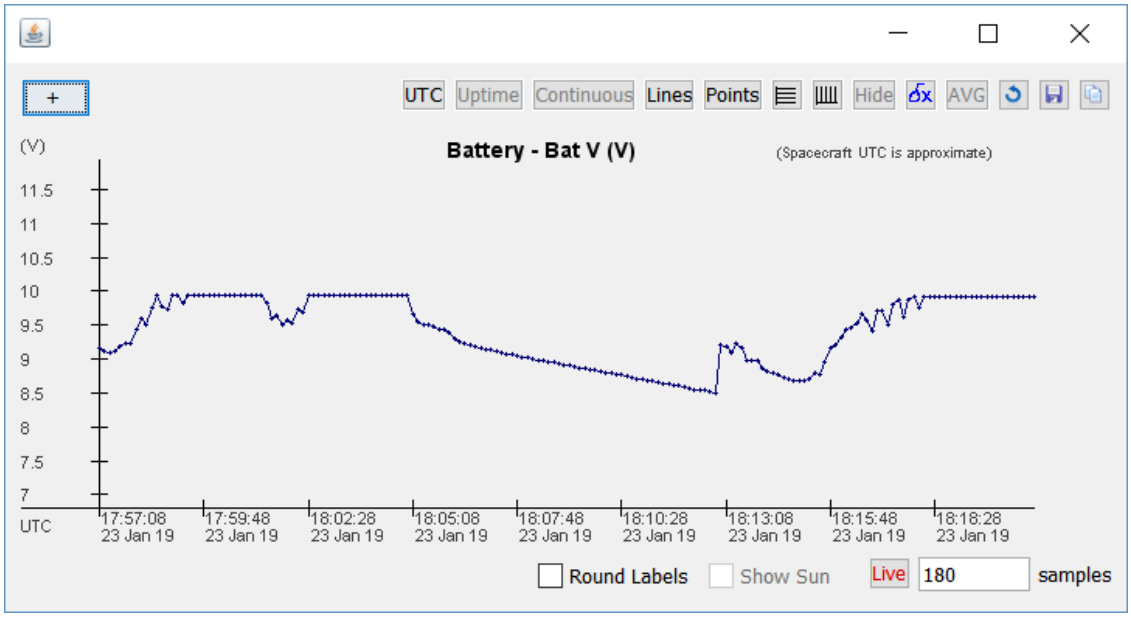
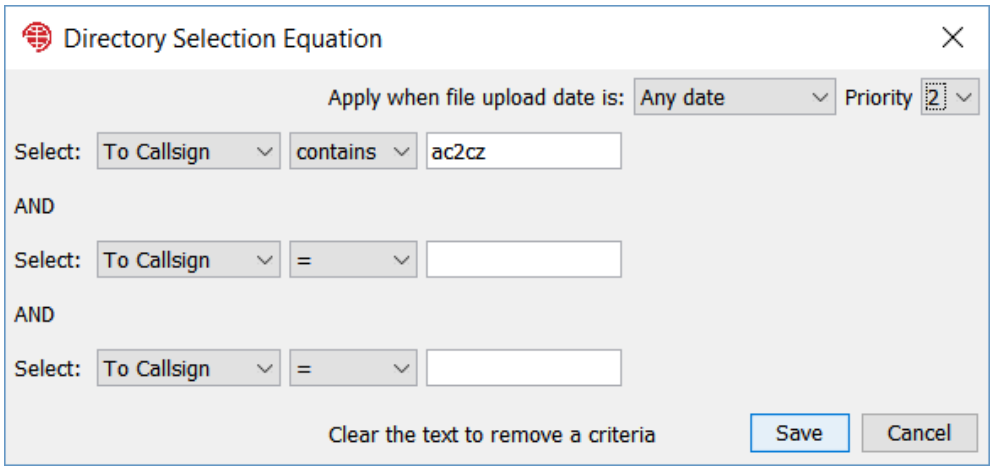


4.4 Directory Selection Equations

It is fun to watch a Pacsat pass and see the files appear. You can select them for download and compose a response in real time. If you are lucky it gets uploaded before the pass is done. But you can not always be in front of the computer. If someone sends a message directly to you, then it would be nice if it was automatically downloaded without you having to give it a priority. To do this you setup a directory selection equation. It's called an equation for historical reasons but you can think of it as a download rule.

On the Spacecraft > FalconSat-3 screen you can see a section of the window for Equations. It is initially empty. Click "Add" to enter an equation, which gives you the screen below:



On this screen I have specified that if "To Callsign" in the Pacsat Header contains the string AC2CZ then set the priority to 2. This applies to a file with any upload date.

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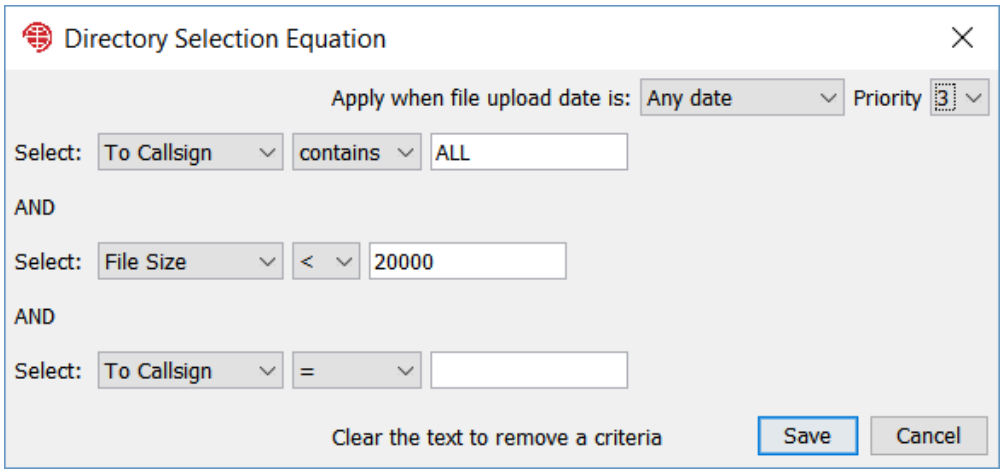
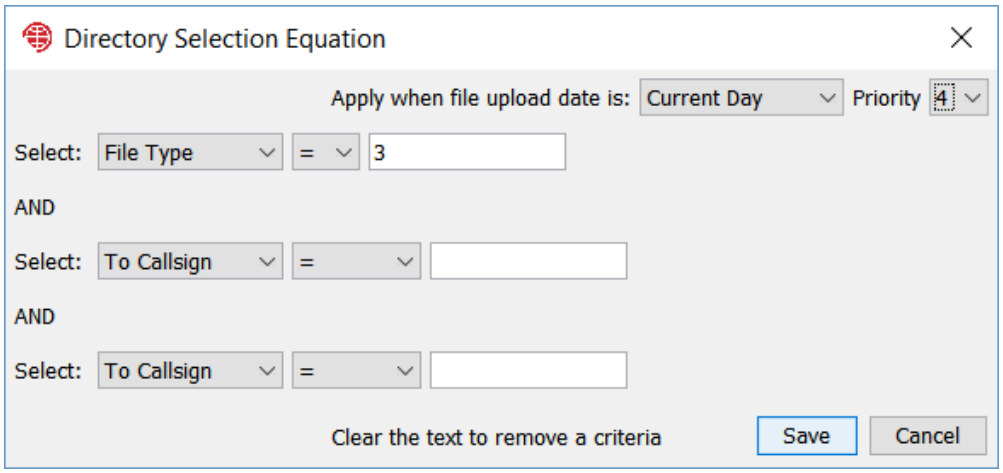


In the example above I have specified that the message needs to be to ALL and the size of the file should be less than 20k. This will exclude large images. Priority is 3.



And then in the example above I have specified the File Type to be "3" which is a Whole Orbit Data (WOD) file. If you are willing to help collect telemetry, set this rule up. Note that it will flag today's file's only, but it does not automatically switch the rule off. You can setup another rule to set File Type 3 to Priority N after 2 or 3 days. This prevents you from getting back logged with older telemetry files.

See the appendix for File Types.

4.5 Uploading Files

If the spacecraft supports uploads and you press "New Msg" on the main screen you get an editor window, ready to create a new message.

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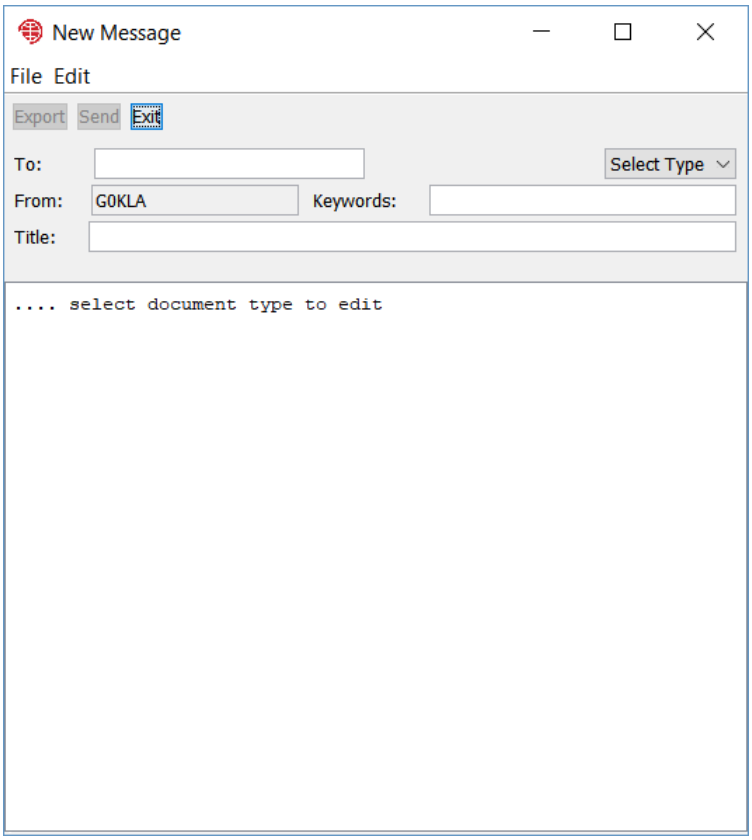

You can not enter any text until you select the type. For a text message pick ASCII. If you want to upload an image then pick JPG. I need to add some more image types. You can pick PNG or some other image formats and it will create the message and upload it. It will probably work with PacsatGround but it may confuse legacy software like WISP. If you test it, let me know what happens.

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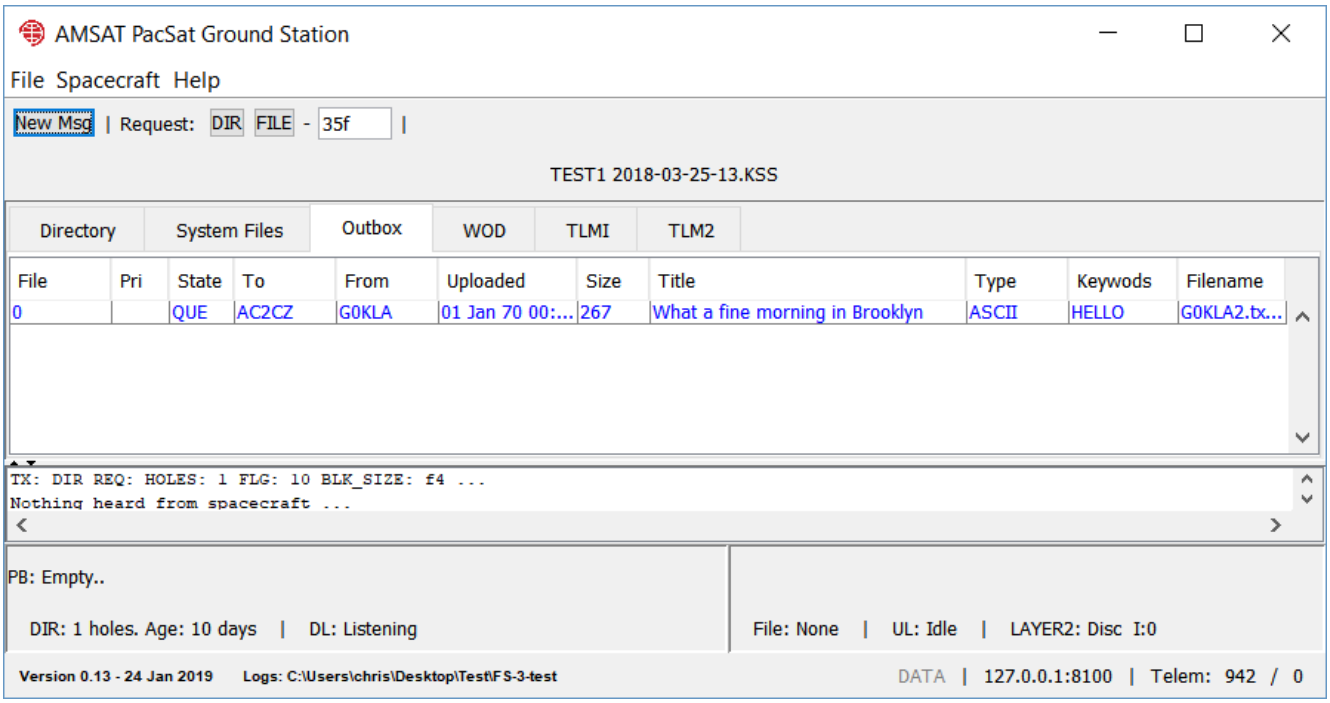
In the "To" Field you put one or more callsigns and/or ALL. Keep the title short and pick some keywords if you want.

Once you hit "Send" the message is added to the Outbox and can be seen on the Outbox tab. Here we can see if the spacecraft has assigned it a file number yet. We also see the State, which is QUE and which becomes SENT or FAIL depending on the result of the upload. If the upload fails then an error message is printed in the log area. I'd like the message to go here in a future release.



5 Appendix

5.1 Starting in Different Directories

You can pass the data directory in at startup, so that you can use scripts or short cuts to run PacsatGround with different data sets. This is most useful to keep a separate copy of server data.

On Linux or MacOs create a shell script with something like the following:

cd <directory where Pacsat Ground is installed>
java -jar PacSatGround.jar /home/chris/radio/fs-3-data

If java is not in your path you will need the full path to java.

On windows go to the folder where PacsatGround is installed.

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- Right click on PacSatGround.exe and drag the icon to the place you want a shortcut. When you release the button you get a menu. Pick "Create Shortcut Here".
- Right click on the new icon and select Properties. In the field "Target" add the Data folder directory after the target as the first parameter passed to the program when it is launched. In fact you can cut and paste the directory from Explorer if you click in the path at the top of the window. If you have spaces in your directory names then the directory path needs to be in quotes.
- Now when you double click the icon it runs PacsatGround using the passed directory as the data folder. It uses a unique set of settings which are stored in the data folder.

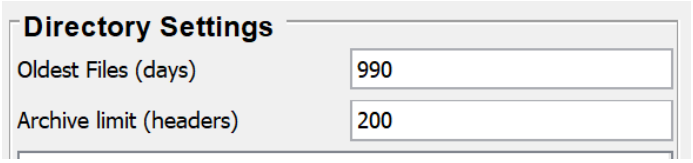
5.2 Archiving the directory

If there are thousands of files in the directory you have downloaded then eventually things slow down and the ground station may not be responsive enough. It may not be able to respond to the spacecraft quickly enough so that transmissions and replies get out of sync. It may seem that you are unable to upload files.

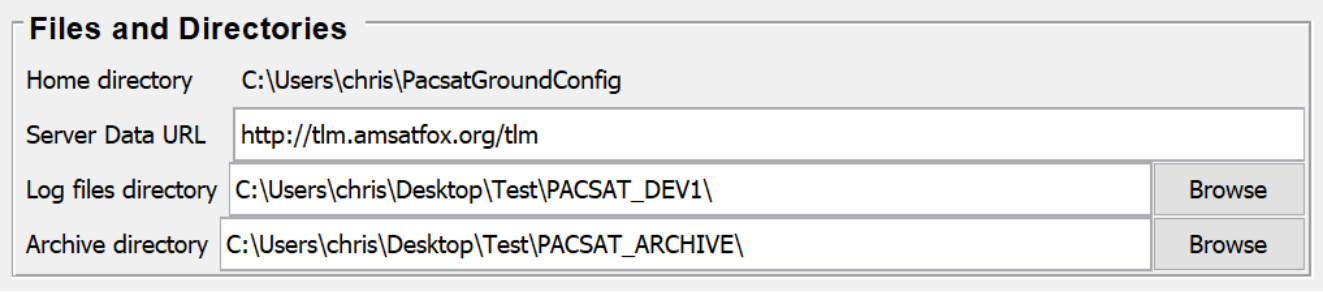
In this case you can archive the directory as follows.

First make a new folder for the archive data. e.g. if your downloaded data is in:
C:\Users\chris\Desktop\Test\PACSAT_DEV1
then make a folder like:
C:\Users\chris\Desktop\Test\PACSAT_ARCHIVE

On the Spacecraft > FalconSat-3 screen (or the screen for Mir-Sat-1), decide how many headers you want to keep by specifying the Archive Limit. This will be the number of headers and files that are kept after you archive.



On the File > Settings screen, select the archive folder. For example, I have picked the PACSAT_ARCHIVE folder below:



Then run the archive with File > Archive The Directory

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This will prompt to comfirm. If you only want to archive one of the spacecraft then just say yes to that one. It will move all of the headers and their associated files into the archive folder. It will keep the most recent files.

Archiving should be an infrequent operation, You do not need to archive every day, week or even month. You can't archive into the same folder (because I did not write that code) so next time you archive you will need to pick a new empty folder.

You can open an archive folder whenever you want. Go to File > Settings and change the Log Files Directory to the archive folder. Then you are looking at the archived files. Change it back for live operation. Or use the approach descibed in the previous section to setup a script or icon to open an archive folder.

5.3 File Types

This is the list of Pacsat File types I have.

0 ASCII Text message.
2 Bulletin Board Satellite Gateway Files
3 UOSAT whole orbit data
6 MSDOS EXE file
7 MSDOS COM file
8 Keplerian elements - NASA format
9 Keplerian elements - AMSAT format
12 Binary file(s).
13 Multiple files, all ASCII text
14 Picture file - GIF format
15 Picture file - PCX format
16 Picture file - JPG format
17 Confirmation Message
18 Multiple destination SatGate files
19 Internet forward files
200 Config. files U/L from command stations
201 AL FTL0/PB activity logs
202 BL Broadcast logs
203 WD whole data logs
204 ADCS logs
205 TDE data
206 SCTE data
207 Transputer logs (including EISLOG)
208 SEU logs (ELTLOG)
209 CPE files (UO3)
210 Battery charge logs
211 Image files
212 PL* (SPL Logs)
213 CU* (PCT Log Files)
214 PC* (PCT Command Logs)
215 Quick look image files
221 CCD Image files (KO23)
222 CPE Result files (KO23)
255 All others not fitting in the above

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5.4 Troubleshooting

The TNC seems to be receiving data but nothing is shown in Pacsat Ground	Make sure you are in KISS mode. Try connecting to the TNC from a normal terminal and putting it manually into KISS mode. If there is a special way to put your TNC into KISS let me know. Right now it uses the TNC2 compatible method, sending the string KISS ON followed by RESTART. Also note that it takes the TNC out of KISS when it exits by sending a KISS frame with one byte ff. (The whole frame is c0,ff,c0)
I never transmit any data from the TNC even though PacsatGround sends data to it	Are you really in Full Duplex mode?
It crashed, what do I do?	Log an issue on github.com/ac2cz/Falcon/issues or send an email to the author g0kla@arrl.net
I connect to my computer using a Remote Desktop Connection (RDP) and Pacsat Ground is always not running.	This seems to be a Windows "feature". When you connect the RDP connection kills something in the audio subsystem that upsets Java. This is outside the Pacsat Ground code base and I don't have a fix. I recommend using AnyDesk for remote connections.
Everything has got really slow and I no longer seem to be able to upload files	The directory may be too large and your transmissions are out of sync with the replies from the spacecraft. Reset or archive the directory. See the Appendix 5.2

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