

Phoenix CubeSat SpaceCap File & Frequency Licensing Tips

Document Purpose & Scope

The Phoenix CubeSat was registered with an Experimental License from the FCC, operating in the amateur bands at a frequency of 437.35 MHz. Obtaining this frequency license took **roughly a full year** in total and required several resources to be submitted to the IARU, FCC, and ITU. Along the way, the team gained a much better understanding of the licensing process. Ultimately, this document serves to:

1. Provide advice and insight into frequency licensing, based on the experience of the Phoenix team
2. Highlight one of the primary resources that must be submitted to the FCC: the SpaceCap file
 - a. Screenshots of the SpaceCap file submitted to the FCC to obtain a frequency license, along with an explanation on how this was filled out and how certain values were chosen

Advice & Insight on Licensing

General Advice

1. **Read section 5 of the CubeSat101 guide**
 - This covers the licensing process for
2. Licensing may seem like a very intimidating process, but it isn't as scary as it seems. Once you are approved for a launch, NASA will follow you closely on this. They have seen numerous CubeSats go through this process over the years, and are therefore an excellent resource to guide you in resolving any issues you have along the way.
 - Further, if anything new comes up in the process of acquiring a frequency license, talk to your NASA managers. They have the best insight on all the necessary policies and can help resolve information that is unfamiliar or may not seem right.
3. As you go through the licensing process, I highly recommend trying to find contacts at the FCC and IARU who can answer questions for you on anything that may be unclear with the specific details you have to provide them.
 - If you plan to operate on amateur frequencies and need to submit an application to the IARU, don't be afraid to send your contact your IARU application for feedback. Doing so ensures that your application will be approved the first time you officially submit it. We did this, and the licensing process went very smoothly.
4. When should you start this process?
 - As mentioned above, it took us **roughly a full year** to go through the full licensing process, from filing the IARU application to being granted the official frequency license from the FCC. This includes time spent completing all of the required materials, having these reviewed and approved, and discussing the details of licensing requirements in between. As such, it is highly, highly recommended to start licensing processes **as soon as possible**. Typically, you will want to start this once your spacecraft and ground station comms system is defined and you have been approved for a launch.
 - If you're confused on anything, get in touch with other student teams who have done this before, or go over the licensing process with NASA once you are approved for a launch and start working with them on getting everything in order.

Notes on filing Form 442 with the FCC (for university student teams)

Before submitting Form 442, keep in mind that this must be signed by someone who is authorized to sign for the university. The application involves electronic signatures, by which the University certifies to a number of things. Therefore, it should be signed off by someone who has the authority to act on behalf of the university, not the student lead.

Other FAQ on Frequency Licensing

Can you operate on the same frequency as another cubesat?

Yes, this can happen, especially as more CubeSats are launched. However, the FCC has a very good hold on these licensing regulations and organizes this very well. However, it is still possible to run into issues with frequency allocations when it comes to the operations phase. On Phoenix, we encountered the 1/1,000,000 chance where we not only had a frequency buddy, but this CubeSat was also scheduled to deploy with us. While this seemed concerning at first, the situation really just presented a small obstacle to work around. Each CubeSat has its own distinct health beacon and its own unique set of callsigns, which makes it very easy to distinguish the spacecraft from one another. As a result, this didn't present much of an issue for either team when it came time to identify each CubeSat and its associated TLE after deployment. Over time, the CubeSats will separate from one another after deployment, which makes the process easier as well.

When this occurred, we made sure to get in touch with the operators of our frequency buddy to work out the details further and make sure neither spacecraft stepped on the other's transmissions. However, the most important step both teams took in this situation was informing the amateur radio and SatNOGS communities that two CubeSats, deploying on February 19, 2020, would be operating under the same frequency, and with very similar transceiver configurations (radio protocols, modulation, etc). Further, we pointed them to our website, which detailed the beacon operators should expect and the callsigns associated with the spacecraft.

Did the ASU ground station need its own frequency license?

The student team intended to operate Phoenix from the ASU ground station, which was not officially registered under anyone at the time of applying for a frequency license. Since Phoenix was to be licensed under an Experimental authorization in the amateur radio bands, we did not need to acquire a separate license for the ASU ground station.

The rationale for this (as told by the FCC) was that the ground station information and CubeSat are under the responsibility of ASU and not an individual. The combination of our SpaceCap file and attachments included as much information as the FCC needed on our ground station, so no further action was required.

What call sign do you transmit to the CubeSat with?

If you are using the amateur radio frequencies, anyone operating the spacecraft from the ground station must have a ham radio license. While you will be transmitting from your university's ground station, you will transmit packets using your callsign as the source address, and the satellite's callsign as the destination address.

Phoenix SpaceCap File Details

Overview

What are SpaceCap and SpaceVal?

SpaceCap - Windows application which captures the characteristics of your spacecraft's communications system and ground system.

SpaceVal - This software validates the information included in your spacecap file in that it evaluates whether errors have occurred based on the way you have added information on your spacecraft (space station) or ground station (earth station). This is also a Windows application.

General tips for completing the SpaceCap file

1. Make sure you have the most recent software version for both SpaceCap and SpaceVal
2. You will submit only one spacecap file, which will include details for all uplink and downlink characteristics from the spacecraft to a ground station.
3. The FCC/ITU will not accept files with any fatal errors.
 - a. It is highly important that you run your spacecap file through SpaceVal before you submit this to the FCC. ensure there are no errors in the file before submitting. Warnings, however, might be ok. It would be best to double check these with your contact at the FCC.

Submitting the spacecap file

When the SpaceCap file is complete (ie: completely filled out and verified using SpaceVal), this should be sent to your contact at the FCC, where it will be evaluated from there. When you submit the spacecap file, you will need to **edit the file name to remove the .mdb extension** at the end and replace it with something else (ie: txt, itu, etc.). It will not go through the firewall at the FCC otherwise.

To clarify,

Original file format: SpaceCap.mdb

File format to submit to the FCC: SpaceCap.itu

Any attachments should be uploaded to the FCC's Electronic Licensing Service (ELS) and submitted to your contact at the FCC.

Version Info

The following pages detail the SpaceCap file that was submitted to the FCC for the Phoenix CubeSat. The SpaceCap file was completed and verified using the following versions of SpaceCap and SpaceVal.

SpaceCap Version: V8

SpaceVal Version: V8

Opening Old Files & Starting New Ones

1. Open the app
2. Should be in the 'API' tab of the app
 - a. To start a new notice, click on 'New Notice'
 - b. To open an old one, follow the steps in Figure X

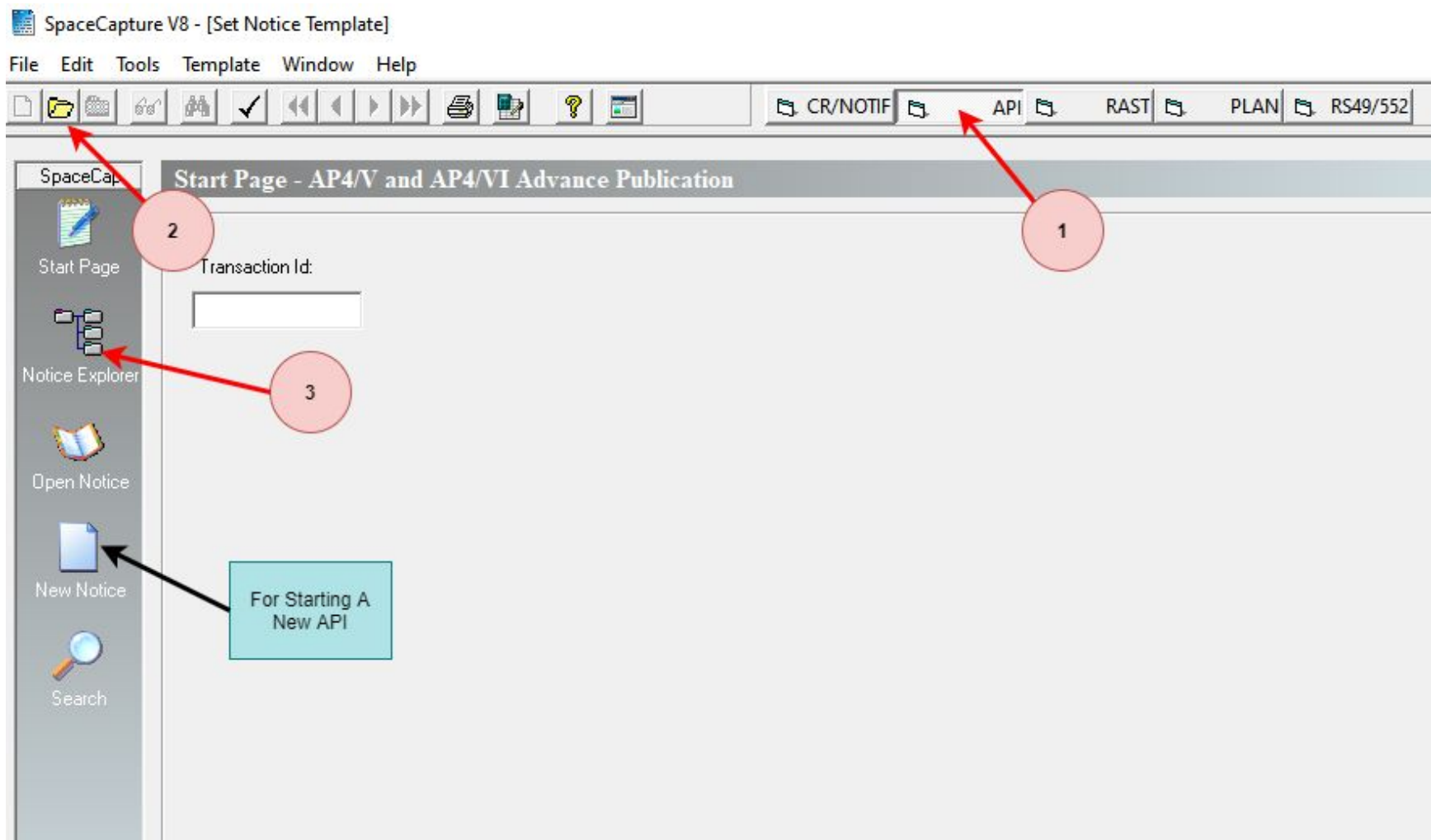


Figure 1: SpaceCap Home Page

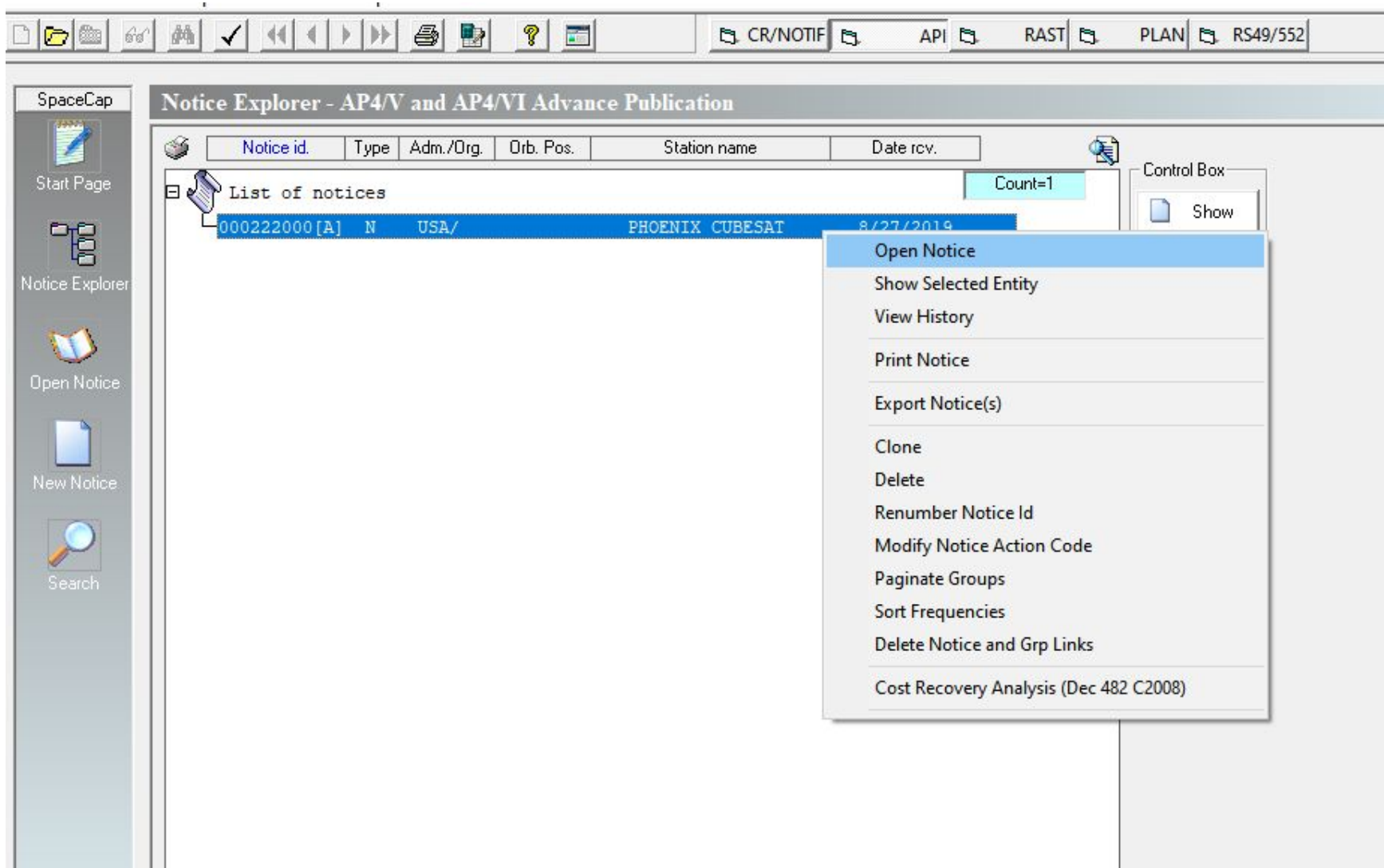


Figure 2: SpaceCap Notice Explorer

Notice page

- **A1a: Identity of the satellite**
 - o Type in your satellite's name, since it won't be in the official list yet.
 - o The ITU adds your satellite to the official list once you are licensed.
- **Section II article 9**
 - o It is assumed that most cubesats aren't subject to coordination
- **A4b3a and A4b3b:**
 - o Necessary to fill out only if the station operates in the freq range of 3400-4200MHz
- **List of available beams**
 - o Clicking on these allows you to switch between beams to edit parameters
- **A4b4: Orbital plane button**
 - o Opens a new plane where you add your orbital parameters (inclination, apogee, perigee, etc)

The screenshot displays a web interface for satellite registration, divided into three tabs: Notice, Beam, and Remarks. The 'Notice' tab is active, showing the following details:

- Notice Id:** 222000
- Advance Publication:** 4/18/2018
- Status:** 01
- Date:** MM/DD/YY 8/27/2019
- Administration:** USA
- A1f1. Notifying Administration:** USA
- A1f2. Notice submitted on behalf of these administrations:** USA
- A1f3. Intergovernmental Satellite System:** (empty)
- Network Type:** Non GeoStationary Satellite Network
- Notice intended for:** Add, Mod, Sup
- BR Identification No. of the Satellite Network to be Modified:** (empty)
- A1a. Identity of the Satellite Network:** PHOENIX CUBESAT
- A4. Orbital Information:**
 - A4b1. Number of Orbital Planes:** 1
 - A4b2. Reference body:** (T) Earth
 - A4b3a. Nbr of Satellites to NH:** (empty)
 - A4b3b. Nbr of Satellites to SH:** (empty)
- A4b4. Orbital Plane Information:** (button with satellite icon)
- Section II Article 9:** Not Subject to coordination
- List of Available Beams:**
 - Beam 20KF1D
 - Beam ERAU20KF
 - Beam 20K0F1D
 - Beam ERAU20K

Figure 3: Notice Page

Beam

- **83c1. Copolar Radiation Pattern Id**
 - Clicking the 'eye' button reveals a list of Rad patterns to choose from
 - **Our Pattern ID = 610 ND-SPACE APSND_499v01**
 - Non-directional space station antenna pattern (RX/TX), as Phoenix had an omnidirectional antenna
 - For special patterns, you'll have to provide the equations for these to the ITU. This box references the attachment you've added
 - Descriptions of the pattern Id can be found here: <https://www.itu.int/en/ITU-R/software/Pages/ant-pattern.aspx>
- **Adding uplink/downlink beams**
 - You will only submit one SpaceCap file, so uplink and downlink parameters must be described in different beams
 - New beams should also be created to represent different frequency bands (if using more than one transceiver)

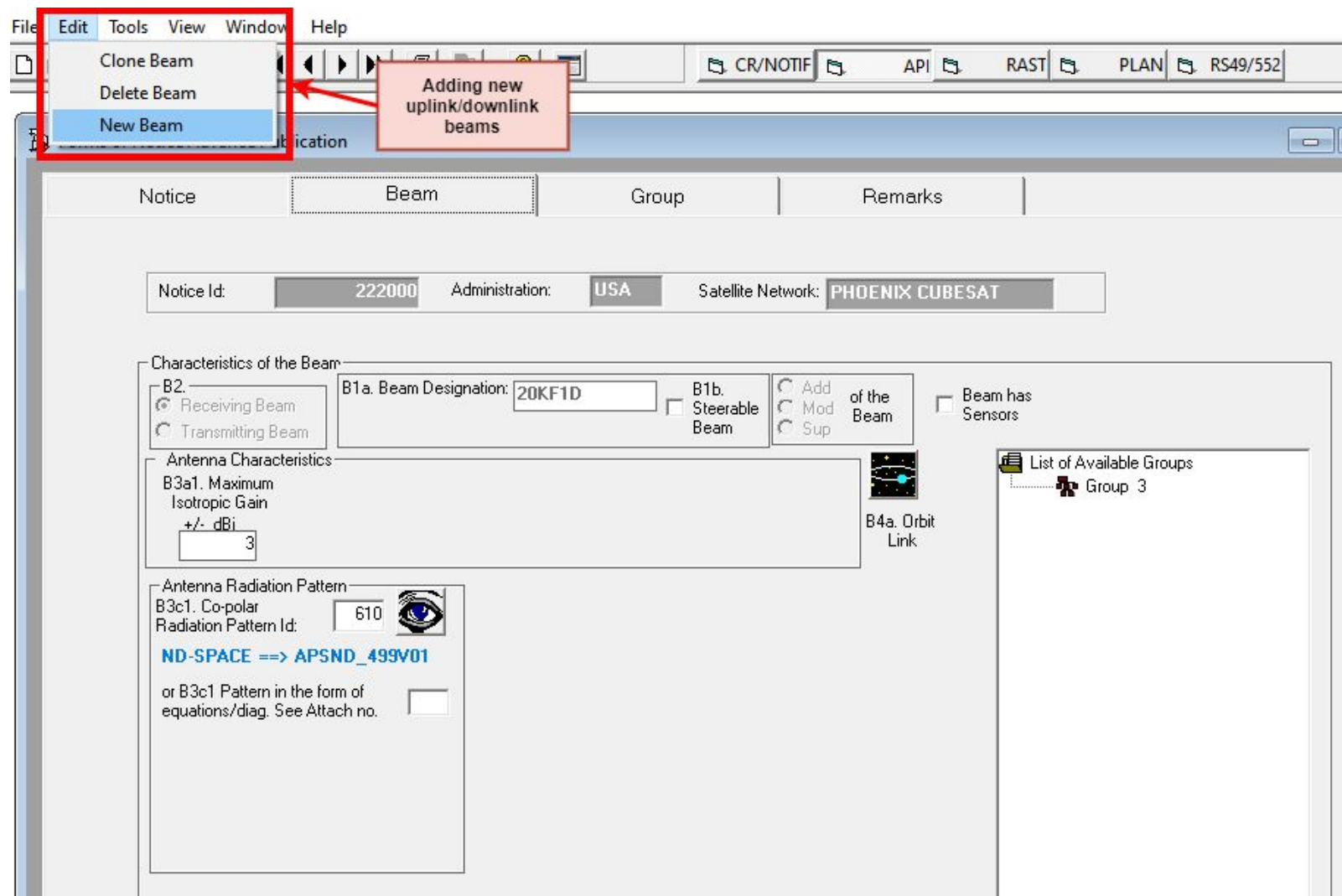


Figure 4: Beam Page

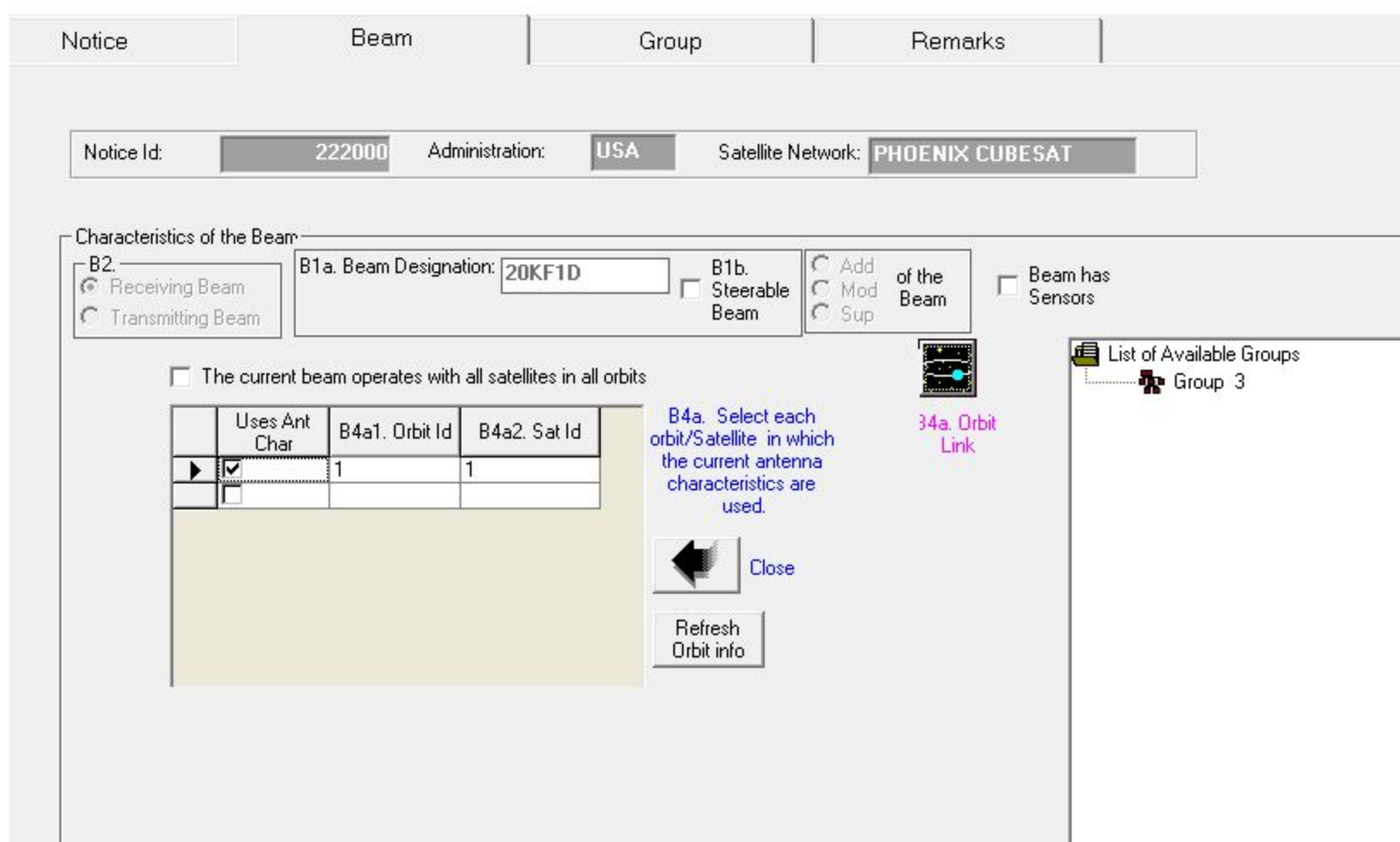


Figure 5: Orbit Link

Group Tab

- **C5a: Noise Temperature**
 - Taken from from link budget
- **C4a. Class of Station (Cls Station)**
 - **Our selection:** EA = space station in the amateur satellite service.
 - Although we were requesting an Experimental License, we were advised by the FCC to use this classification. As Phoenix was a university student-led CubeSat mission conducting research and operating in the amateur bands, this classification was sufficient. In addition, none of the other options really applied to our spacecraft. You should select the option that best applies to your spacecraft.
 - **If you use EA, then UNCHECK the 4.4 box.** if you don't use EA, you must check the 4.4 box
- **C4b. Nature of Service (Nat Srv)**
 - **Our selection:** CO = station open to official correspondence exclusively.
 - choose the option that best suits your mission. we chose this one because amateurs could send simple pings to the satellite, but could not command it to image or point
- **Note:** This tab, along with the others (Assoc. Earth Station, Emissions, Frequencies, etc.), will need to be completed for each beam you add to your SpaceCap file.

Figure 6: Common Characteristics

- **A3a: Operating Administration**
 - This will be your university. Since ASU was not in the list at the time of filing the Spacecap, we selected “Other” and specified that ASU would be the operating administration in one of our attachments. Your university will be added to the list once the license is obtained.

Figure 7: General Characteristics

Frequencies

- Frequency range, incorporating the bandwidth allocated to us by the IARU

Forms of Notice Advance Publication

Assoc Earth Station Notice | Assoc Space Station Beam | Attachments Group | Emissions | Frequencies

Notice Id: 222000 Adm: USA Satellite Network: PHOENIX CUBESAT Beam Id: 20KF1D R Group Id: 3

C1. Frequency Range

Freq From	Sym	Freq To	Sym
437.25	M	437.45	M

Please note that as of version 7 you are limited to one frequency range per group. You may now specify specific carrier frequencies for each emission on the emission tab. You may also clone the group to add additional frequency bands.

C1. Frequency Range			
Frequency From	k/M/GHz	Frequency To	k/M/GHz
437.25	M	437.45	M

Figure 10: Frequencies

Associated Earth Station

- **C10d1: Class of Station (Cls Stn)**
 - **Our selection:** TA = earth station in the amateur satellite service -
 - chosen to be consistent with the satellite designation. This was advised to us by the FCC.
 - **Notes on classes:**
 - Mobile refers to portable. Most ground stations are fixed.
 - Space research service = a radiocommunication service in which spacecraft or other objects in space are used for scientific or technological research purposes (source: Article 1.55 of the International Telecommunication Union's (ITU) Radio Regulations (RR))
 - Best way to understand these is to google the classifications you don't know
- **C10d2: Nature of Service (Nat Srv)**
 - **Our selection:** CO = station open to official correspondence exclusively.
 - Notes: choose what is most appropriate for your setup
- **Antenna Radiation Pattern**
 - None of the radiation pattern Ids seemed to fit our system. Therefore, we provided our radiation pattern as an attachment. The attachment provides the radiation pattern of the antenna, taken from the hardware datasheet
 - Descriptions of the Earth Station radiation pattern Ids can be found here: <https://www.itu.int/en/ITU-R/software/Pages/ant-pattern.aspx#ESAP>

Notice | Beam | Group | Emissions | Frequencies

Assoc Earth Station | Assoc Space Station | Attachments

Notice Id: 222000 Adm: USA Satellite Network: PHOENIX CUBESAT Beam Id: 20KF1D R Group Id: 3

C10b2. Type of Station: Typical Specific

C10b1. Associated Earth Station Name: ASU GROUND STATION

of the station
 Add
 Mod
 Sup

C10d1. Cls Stn	C10d2. Nat Srv
TA	CO

C10c2. Country: USA

C10c1. Geographical Coordinates

Longitude				Latitude			
Degrees	E/W	Min	Sec	Degrees	N/S	Min	Sec
111	W	55	40	33	N	25	28

C10d. Antenna Characteristics

3. Maximum Isotropic Gain: 15.5 +/- dBi

4. Beamwidth: 30 Degrees

Antenna Radiation Pattern

C10d5a1. Co-polar Radiation Pattern Id:

C10d5a2. Diagram attached. See Attachment no.:

or diagram no in Gims database:

OR

Figure 11: Associated Earth Station

Associated Space Station

- This field was left blank, as we will not be using a satellite to pass data between the spacecraft and the ground. Further, many SpaceCap guides for CubeSats do not include this section.

Figure 12: Associated Space Station

Attachments

- This tab is dedicated to listing the attachments you will provide the FCC/ITU to evaluate your system. As Spacecap is a single file, you are not supposed to be able to insert any links/documents in this tab.
 - All of our attachment files are uploaded online, at the same website where Form 442 was filed with the FCC (aka: the ELS, or Electronic Licensing System).
- In addition to uploading our references to the ELS, we added these to a .zip file and submitted them to our contact at the FCC via email.

Attach No.	Type	File Name	Description
1	File	S/C OVER	MENTIONS NAME OF SATELLITE (FOR SEC. C.1
2	File	GS OVERV	OVERVIEW OF THE ASU GROUND STATION
3	File	IARU LET	IARU COORDINATION LETTER
5	File	YAG_RAD	R 20KF1D Grp 3 Co-polar Radiation Pattern diagram
6	File	UHF_RAD	20KF1D GRPS 1/3 SPACE STATION RADIATION
7	File	SBND_RAD	1M35G1D GRP 2 SPACE STATION RADIATION F
8	File	DSH_RAD	1M35G1D GRP 2 GROUND STATION CO-POLAR
9	File	ERAU RAD	RADIATION PATTERN - ERAU GROUND STATIC

Figure 13: Attachments