How to schedule observations to satellites with VieSched++

This exercise is about the basics of scheduling satellite observations with VieSched++. It assumes that you are familiar with how to generate standard AGN schedules using VieSched++. Have a look at the previous manuals to get started on this. In case you have further questions or troubles using VieSched++ contact *mschartner@ethz.ch*.

> HINT:
> Throughout this document, inputs you have to make highlighted by an orange vertical bar. Optional inputs are highlighted by a green vertical bar. Alternative ways of doing things are highlighted by a blue vertical bar. Hints and tips are highlighted by a gray vertical bar.

> INPUT CATALOGS:
> First, you have to select your catalog files. In addition to the standard sked-catalogs, you need to provide satellite orbits in TLE format. A common data source for TLE files is provided here[1]. You need to generate a new text file with the TLE information. For this tutorial, I have generated a new catalog called *TLE_Galileo.txt* that I will use.
> This is how the content of this file looks like:

> Next, I will load this catalog with VieSched++:

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[1] https://www.celestrak.com/NORAD/elements/
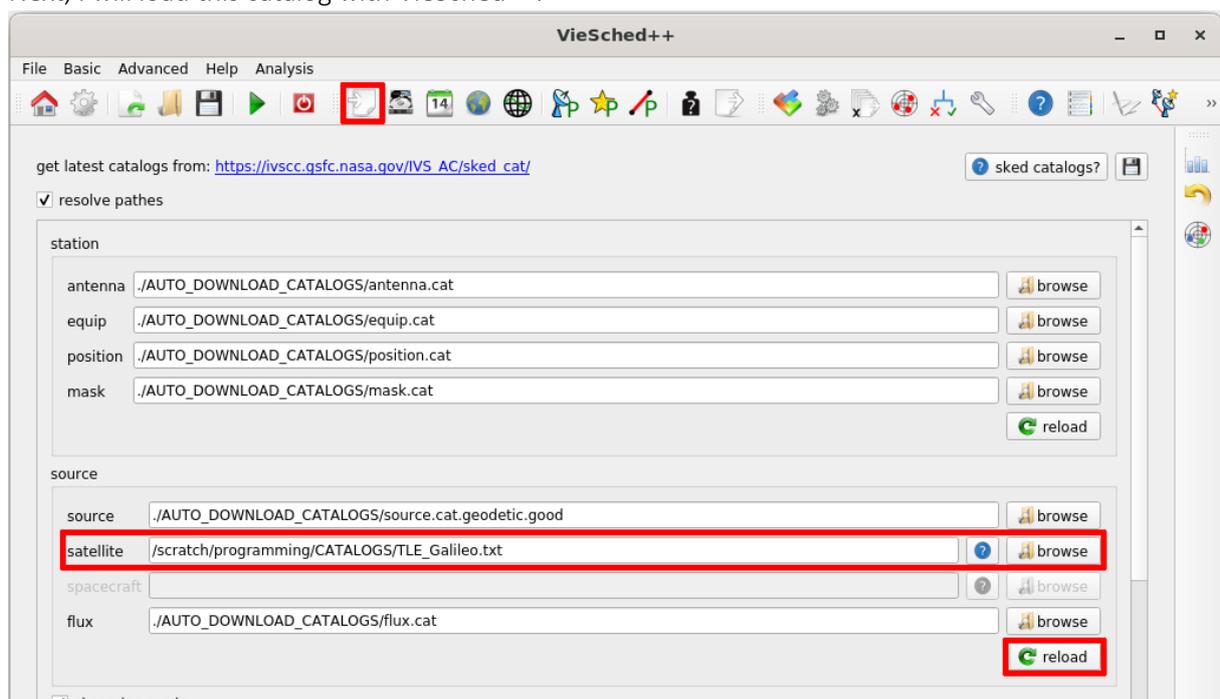
STANDARD GEODETIC SETUP:

First, you should set up all the standard settings for your scheduling similar as done for a standard AGN-only session. This includes:

- defining a station network/start time
- selecting an observing mode
- adjusting the station-, source- and baseline-parameters
- adjusting the weight-factors
- adding calibration scans (if needed)
- defining multi-scheduling parameters
- defining simulation and analysis parameters
- etc.

Have a look at the previous manuals for more information.

SELECT SATELLITES:

Next, you have to select the satellites you want to add to your schedule. I'll only select five satellites in this exercise. Simply click on the satellite names to add them to the list as shown here:
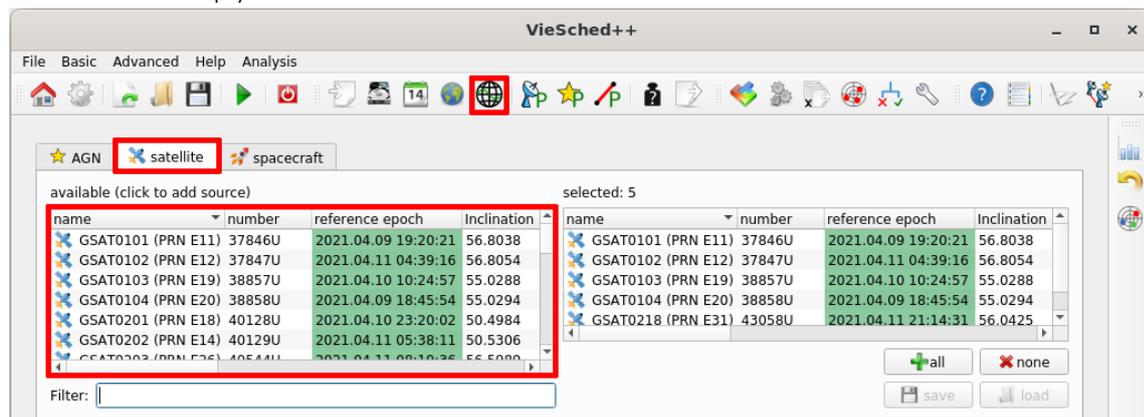
HINT:

The satellite name is used to identify satellites. In case that several TLE entries exist for the same satellite then VieSched++ will automatically use the entry with the reference epoch closest to the observation it is about to schedule. It is only necessary to select one of the multiple TLE entries per satellite in the GUI. In general, using multiple TLE entries per satellite might only be necessary for LEO satellites.

OBSERVING MODE:

Within VieSched++, satellites are treated the same as any other source. Therefore, it is expected that you provide flux density information for satellites as well. However, in general, the flux.cat catalog does not list satellite flux information and instead, you will often simply want to observe a satellite for a fixed number of seconds.

By default, VieSched++ will not schedule sources with missing flux density information. Thus, we have to change the default settings to provide some backup flux density values. Since we are going to use a fixed observation duration for satellites, the actual backup value you set does not matter.
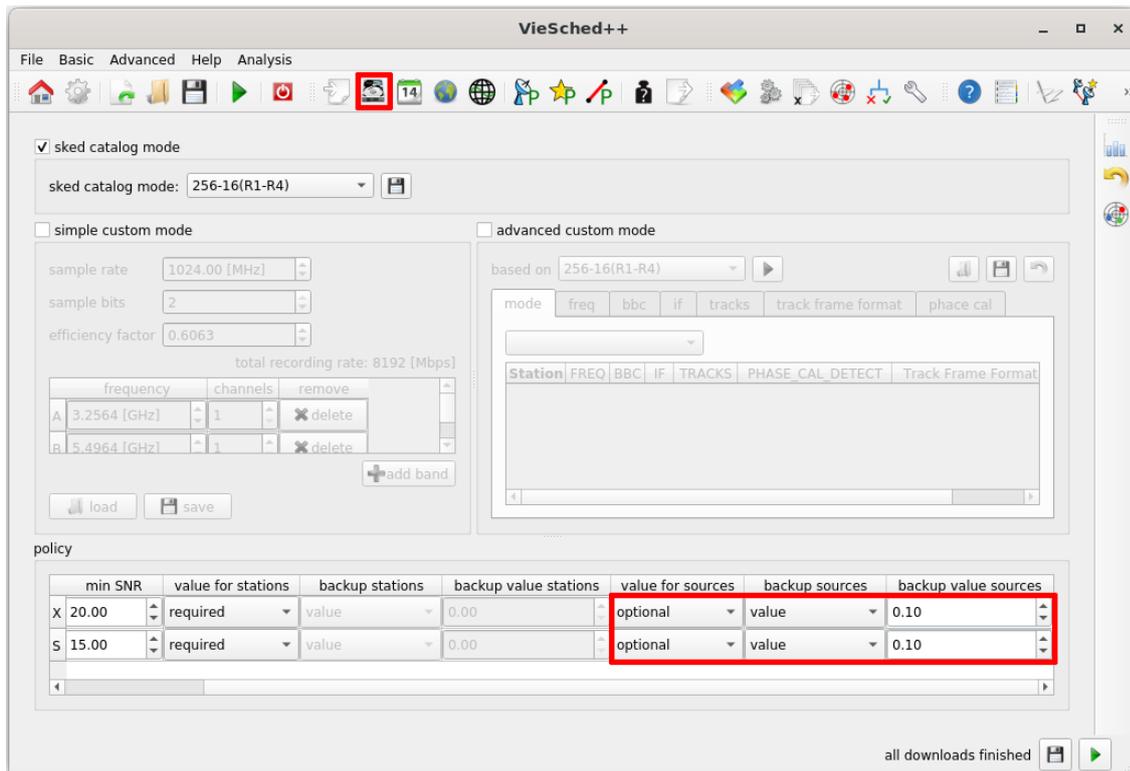
Satellite parameters:

As noted, satellites are treated like any other source in VieSched++. Thus, it is possible to assign custom parameters. In this tutorial, we want to use a fixed observing duration for all satellites. Thus, it is sufficient to simply change the default parameters, that are used by all satellites (the *"__all__"* group).
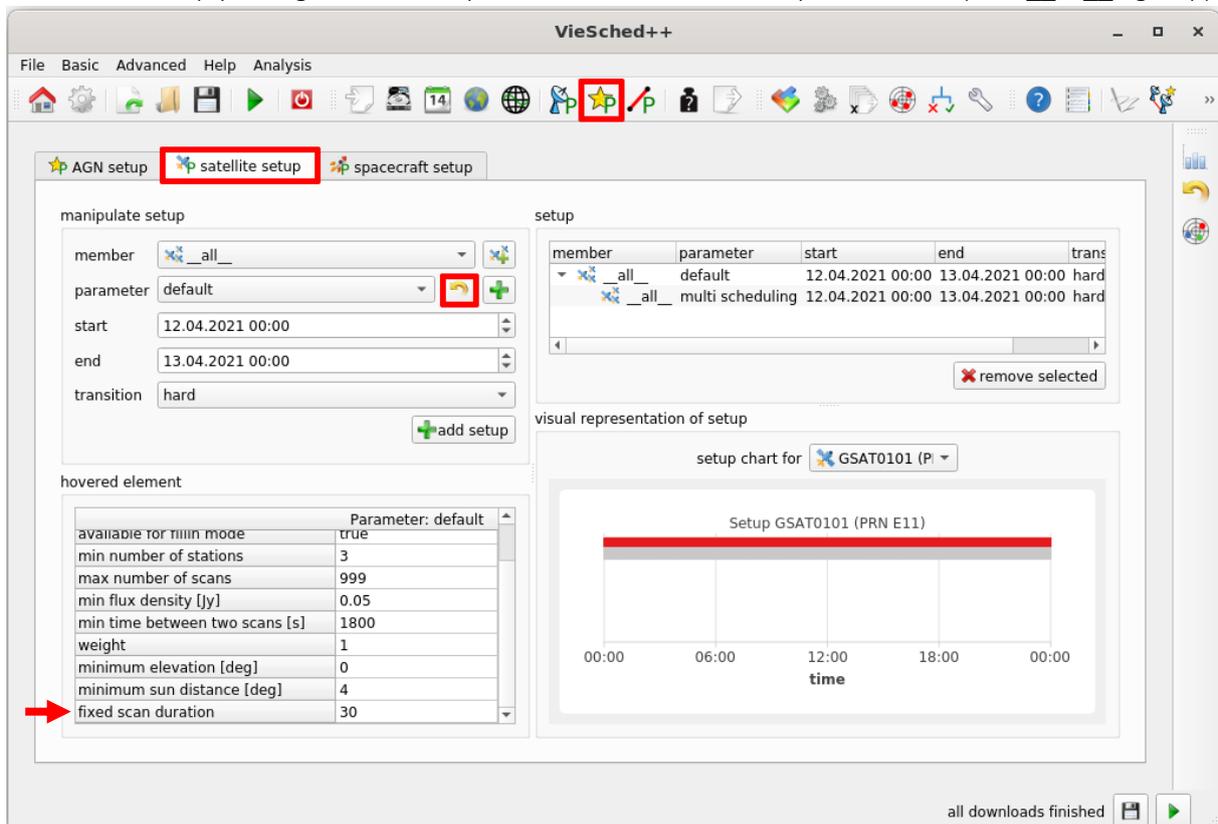
Select *"fixed scan duration"* and change the duration to 30 seconds. Click *"ok"* to close the dialog.
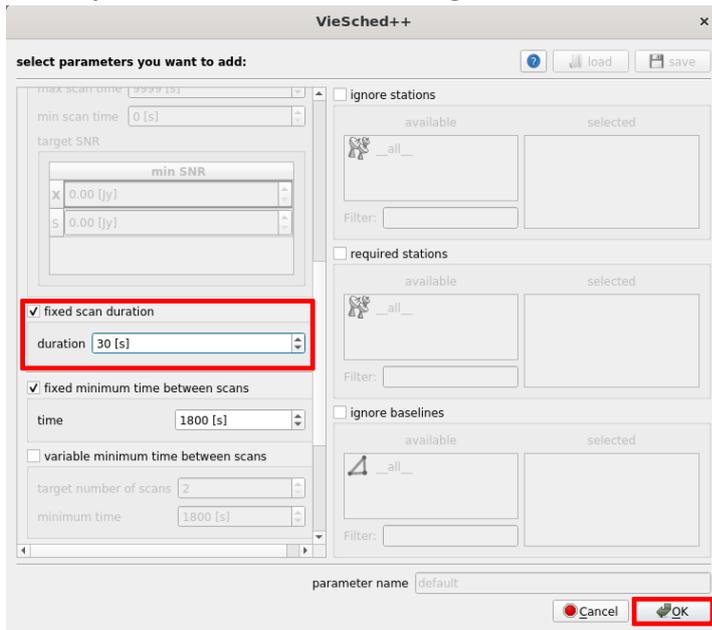
The default parameters should now be changed (check the list entries while hovering the "default" parameters as it is the case in the screenshot on the previous side (red arrow).

HINT:

It might be a good idea to brows through all the possible parameters and default values here. Maybe you want to adjust things a bit. Especially, it might be a good idea to increase the *"weight"* of satellites. The higher the weight-value the more likely it is that the satellite will be scheduled.

Similarly to standard VLBI sources, it is possible to generate groups of satellites and use custom parameters for every group as well as change the parameters over time.

OPTIONAL – ITERATIVE SOURCE SELECTION:

Note that for the iterative source selection, it is possible (and probably advisable) to use different settings for AGNs and satellites. Therefore, there are several default groups. Group *"__all__"* includes all sources (AGNs and satellites) while the default group *"__AGNs__"* only refers to AGNs and the default group *"__satellites__"* only refers to satellites.

In this tutorial, we only use an iterative source selection for the AGNs:
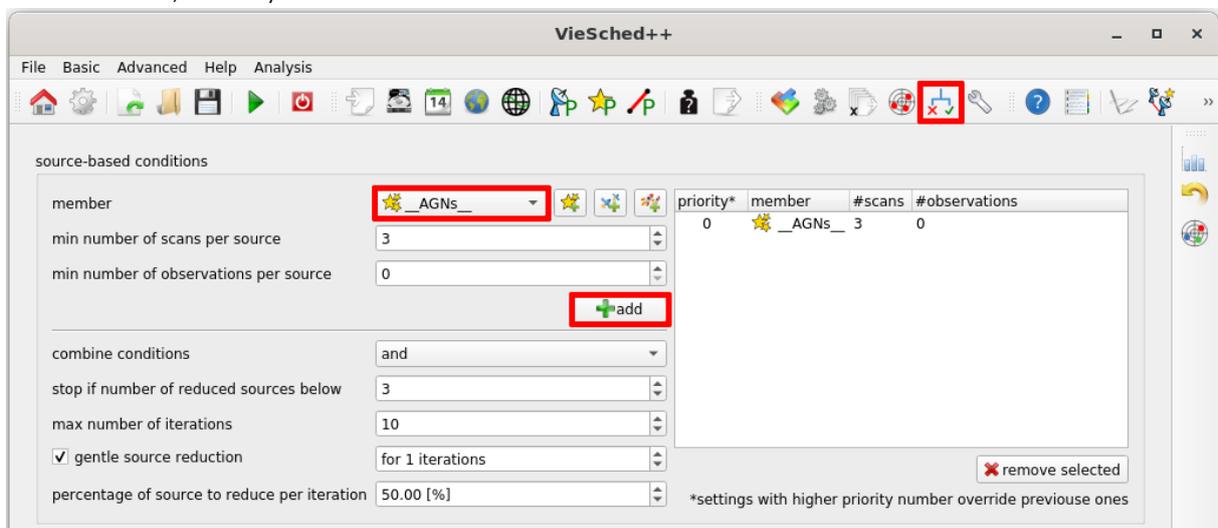
Especially for satellite schedules, a custom scan sequence is often used to ensure a reasonable number of satellite observations in the schedule. In this example, we define that every 5th scan should be on a satellite and the others should observe AGNs.
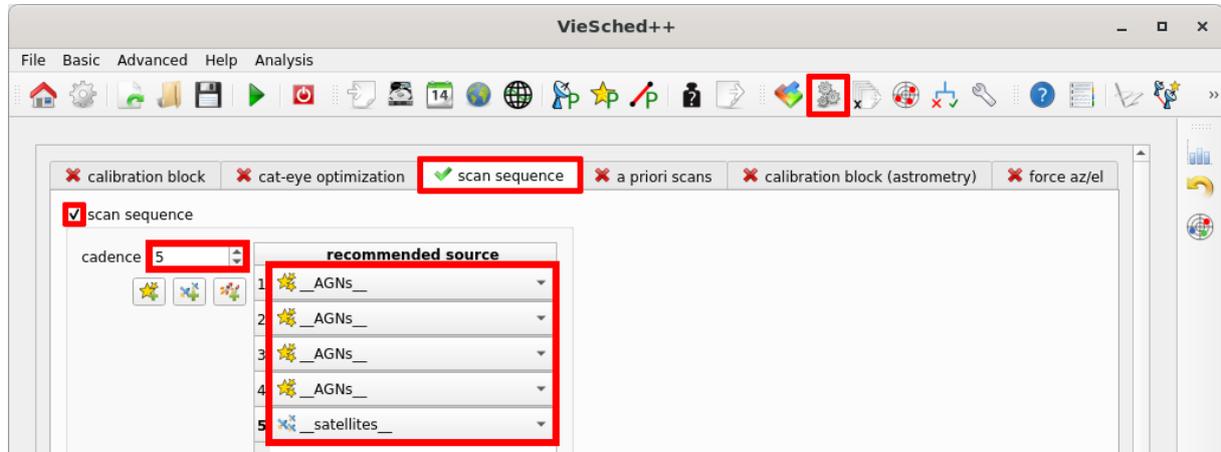
Note:

Please note that the scan sequence you define here may be not observable and thus VieSched++ might ignore it in some cases. Internally, VieSched++ will greatly increase/decrease the weight of sources based on the settings you defined as your scan sequence. However, if there is, for example, simply no satellite available to be observed for a 5th scan, then, VieSched++ can decide to observe a AGN instead of a satellite. Make sure that you set a proper *"fixed minimum time between scans"* in the satellite parameters.

START SCHEDULING:

You can start the scheduling process by clicking on the ▶ button at the bottom right of VieSched++. Have a look at the output files to see if you are happy with the schedule.

IMPORTANT:
It is very important to note that there is still no standard when it comes to satellite observations with VLBI. Thus, there is no standard way to define satellite scans in the .skd, .vex or NGS files. This means, that you have to contact the stations well in advance you want to observe satellites to make sure that you provide them the proper files they need.
In the next sections, we will discuss some important things to note in the output files. I'll again warn you that most likely many of the entries in the output files might not be supported by other software packages like drudge or the field system.

The operation notes file is a human-readable file that summarizes the scheduling result and provides some useful statistics. For statellite observations, the source summary might be of importance. Here it lists how often a source is observed grouped based on 15min blocks:

```
number of available sources:   341
number of scheduled quasars:    80
number of scheduled satellites: 5
number of scans per 15 minutes:
#scans -> char: 1-9 -> '1'-'9'; 10 -> '0'; 11-36 -> 'A'-'Z'; 37-62 -> 'a'-'z'; 63+ -> '#'
.------------------------------------------------------------------------------------------------------------
|                       time since session start (1 char equals 15 minutes)          | #SCANS #OBS |   OBS Time [s] |
| SOURCE           |0  1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21 22 23 |            |   sum  average |
|------------------|+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|------------|----------------|
| ... AGNS ...     |                                                                    |            |                |
|------------------|+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|------------|----------------|
| GSAT0101 (PRN E11)|     1     1    1  1  1  1 1  1       1  1 1 1  1 1 1  1  1 11  1 |   20   357 |  1464      73.2 |
| GSAT0102 (PRN E12)| 1 1  1 1  1  1  1 1 1 1  1            1 1    1 1 1 1    1  1 1   |   21   313 |  1804      85.9 |
| GSAT0103 (PRN E19)|   1    1  1 1    1 1  1 1 1    1        1            1    1 1 1  |   15   222 |  1240      82.7 |
| GSAT0104 (PRN E20)|1 1   1   1  1 1   1  1                     1  1    1  1        |   12   151 |   795      66.2 |
| GSAT0218 (PRN E31)|1 1  1            1    1  1 1 1  1 1 1 1                         |   12   287 |  1112      92.7 |
```

You can see that all our five satellites are observed in the schedule between 12 and 21 times. If you are not happy with the number of satellite scans then go back and adjust the parameters accordingly. Fore example, increase the weight of the satellites, decrease the time between two scans to the same source or adjust your custom scan sequence.

.SKD FILE:

The .skd file does not support satellite observations. As a workaround, new sources are defined for every satellite scan within the $SOURCES block. The source name is the satellite name plus the time in seconds from the session start. The right ascensions and declinations are calculated based on the geocenter.

```
$SOURCES
... AGNS ...
GSAT0218_(PRN_E31):00000        $        04 53 15.2516    +26 58 11.1846  satellite TLE
GSAT0104_(PRN_E20):00404        $        10 14 40.6060    +00 26 41.8147  satellite TLE
GSAT0102_(PRN_E12):01141        $        03 42 09.8607    +30 30 38.3014  satellite TLE
GSAT0218_(PRN_E31):02253        $        05 34 19.2350    +14 09 24.2033  satellite TLE
GSAT0103_(PRN_E19):03211        $        09 26 57.0014    -16 03 40.5821  satellite TLE
GSAT0102_(PRN_E12):03431        $        04 37 55.4173    +42 21 54.5806  satellite TLE
GSAT0104_(PRN_E20):03544        $        11 07 44.2057    +18 32 59.5542  satellite TLE
```

In the $SKED block, the corresponding sources are listed. Note that by default some software packages only support 8-digit long source names. This is not the case here.

```
$SKED
GSAT0218_(PRN_E31):00000  10 SX PREOB  21109170000        69 MIDOB        0 POSTOB I-S-1-N-T-B-V- 1F000
1334-127   10 SX PREOB  21109170000        67 MIDOB        0 POSTOB J-AWY- 1F000000 1F000000 1F000000 YY
0202+319   10 SX PREOB  21109170138        94 MIDOB        0 POSTOB KWICSC1CN-T-BCVC 1F000000 1F000000 1
1451-375   10 SX PREOB  21109170200       509 MIDOB        0 POSTOB J-AWYW 1F000000 1F000000 1F000000 YY
0059+581   10 SX PREOB  21109170340        63 MIDOB        0 POSTOB KWICSC1CNCT-BCVC 1F000000 1F000000 1
2214+241   10 SX PREOB  21109170504        60 MIDOB        0 POSTOB KW1CNC 1F000000 1F000000 1F000000 YY
NRAO150    10 SX PREOB  21109170514        75 MIDOB        0 POSTOB ICSCT-BCVC 1F000000 1F000000 1F00000
3C418      10 SX PREOB  21109170643        34 MIDOB        0 POSTOB KW1CNC 1F000000 1F000000 1F000000 YY
GSAT0104_(PRN_E20):00404  10 SX PREOB  21109170644        37 MIDOB        0 POSTOB B-V-Y- 1F000000 1F00
```

.VEX FILE:

Within the .vex file, satellites are defines in the TLE format following the VEX2 standard. Please note that some stations and software packages might not support VEX2 yet. It is your responsibility to ensure that the .vex file can be parsed by all stations correctly.

```
def GSAT0101 (PRN E11)
    source_type = tle
    tle0 = 'GSAT0101 (PRN E11)'
    tle1 = '1 37846U 11060A   21099.76413826 -.00000100  00000-0  00000-0 0  9996'
    tle2 = '2 37846  56.8038  33.1582 0004323 351.7251   8.2446  1.70475351 58828'
enddef;
```

Within the NGS file, the satellite TLE information is provided in the header.

```
satellite GSAT0101_(PRN_E11)
   GSAT0101 (PRN E11)
   1 37846U 11060A   21099.76413826 -.00000100  00000-0  00000-0 0  9996
   2 37846  56.8038  33.1582 0004323 351.7251   8.2446  1.70475351 58828
```

The NGS files format is based on a fixed character position-based layout where only 8-character long source names are supported. Additionally, some software packages only support source names up to 8-characters as well. However, this is not the case in these NGS files if your satellite names are longer than 8 characters:

```
MATERA    NOTO      GSAT0218_(PRN_E31) 2021 04 19 17 00   0.0000000000                    101
    0000000.00000000     .00000  -000000.0000000000     .00000 0     I        102
     .00000     .00000     .00000     .00000   0.000000000000000         0.      103
      .00    .0      .00    .0       .00    .0       .00    .0                   104
   -.00000    -.00000     .00000     .00000     .00000     .00000                105
    0.000     00.000    000.000    000.000     00.000    00.000 0 0              106
      0.0000000000     .00000        -.0000000000     .00000   0                 108
       0.00000000     .00000       0.0000000000     .00000 0     I               109
```

Make sure that the software you are using supports this as well (or use satellite names with < 8-character length).

So far, satellite observations are completely ignored during simulations as can be seen in the simulator file:

```
Ignoring observations to the following sources:
    GSAT0101 (PRN E11) (20 scans 357 obs)
    GSAT0102 (PRN E12) (21 scans 313 obs)
    GSAT0103 (PRN E19) (15 scans 222 obs)
    GSAT0104 (PRN E20) (12 scans 151 obs)
    GSAT0218 (PRN E31) (12 scans 287 obs)
Number of simulation runs: 1000
Number of observations:    11862 of 13192
```