MilliBox®

ANTENNA TEST SYSTEMS

OTA your way!

GIM0x User Manual

Hardware p11 ›

Software p43 ›

Troubleshooting p161 ›

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HS-GIM0x-024_1
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Before you start:

Thank you for your interest in Milliwave Silicon Solutions products. MilliBox GIM0x is designed and manufactured for the satisfaction of its users. If you have any concerns, please do not hesitate to contact millibox@milliwavess.com.

In order to operate the 3D positioner inside the MilliBox chamber or not, you need to have a host machine, preferably a Windows PC (even though all the hardware and software are compatible with other operating systems, like Linux or Mac OS machines). Everything else is supplied in the GIM0x package.

You will need some basic skills in computer science, especially in Python script, to integrate your test environment into the MilliBox context. You will also need some basic skills in mechanical engineering and electrical engineering to attach your DUT to the 3D positioner and connect it to your test environment.

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Laser Safety and Operation:

Laser Description
Wavelength: 645-665nm (RED)
Maximum output: <1mW
Class 2
Beam divergence: Crosshair

Laser hazards
Eye injury from beam: Do not look into the direct or reflected beam; can cause eye injury up to 50 ft (15 m) away.
Visual interference (glare) with pilots and drivers
Interferes with vision up to 1050 ft (320 m) away. Can be a distraction up to 2 miles (3.2 km) away. NEVER point any laser towards aircraft or vehicles; it is unsafe and illegal.

Safe use guidance
Class 2 lasers are considered safe for accidental eye exposure.
Do not look or stare into the beam. Do not aim at aircraft or vehicles.
When a 3D positioner 3D plot is performed, the laser may point to any possible direction in space unpredictably and the laser should be TURNED OFF.
Only turn ON the laser for fine alignment calibration.
Always operate the 3D positioner 3D plots inside a closed enclosure without human presence inside and with the laser OFF.
Do not operate the laser when it is detached from the 3D positioner, or during operation on the 3D positioner like for example placing a DUT or doing DUT wiring.
Always keep your body especially eyes and hands away from the laser aperture since: EXPOSURE NEAR APERTURE MAY CAUSE BURNS.

Operation
The laser is turned on and off by powering the USB Type A plug attached to it. The USB Type A plug can be connected to any USB charger or USB port of a device, for example a

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computer. There is no software access, driver or control on this USB plug it only sources power from the port.
During calibration look toward the bull's eye target on the horn post side where the alignment with the crosshair pattern is done and not toward the 3D positioner where the laser aperture is.

Eye Protection
Class 2 lasers are considered safe for accidental eye exposure, but eye protection glassware specifically designed for RED laser 600 to 700nm is available on the market. Look for OD4+ and above rated products.

Maintenance
During any maintenance of the 3D positioner or the laser component, always disconnect the laser from its main power supply (USB), disconnect the 3D positioner from its power supply first. The laser can be detached from the 3D positioner rotating platform and replaced, if necessary, without tools. NEVER attempt to service, open, rewire or repair the Laser component itself from your end, it is a self-contained unit which can be replaced but cannot be repaired. If found defective, please contact Milliwave Silicon Solutions Inc. for a replacement.

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Important Warnings:

Read this entire manual fully once before attempting anything with the 3D positioner MilliBox GIM0x.

If the equipment is used in a manner not specified in this manual, the protection provided by the equipment may be impaired.

The entire unit should be installed and securely attached to a work bench before any steps in this manual should be carried out.

Unplug the power to the 3D positioner when not in use. Whenever power is supplied to the 3D positioner, the motors are applying control torque to the 3D positioner.

Never move the 3D positioner axis position manually when the power to the motor is ON or when the USB controller is attached to the host PC.

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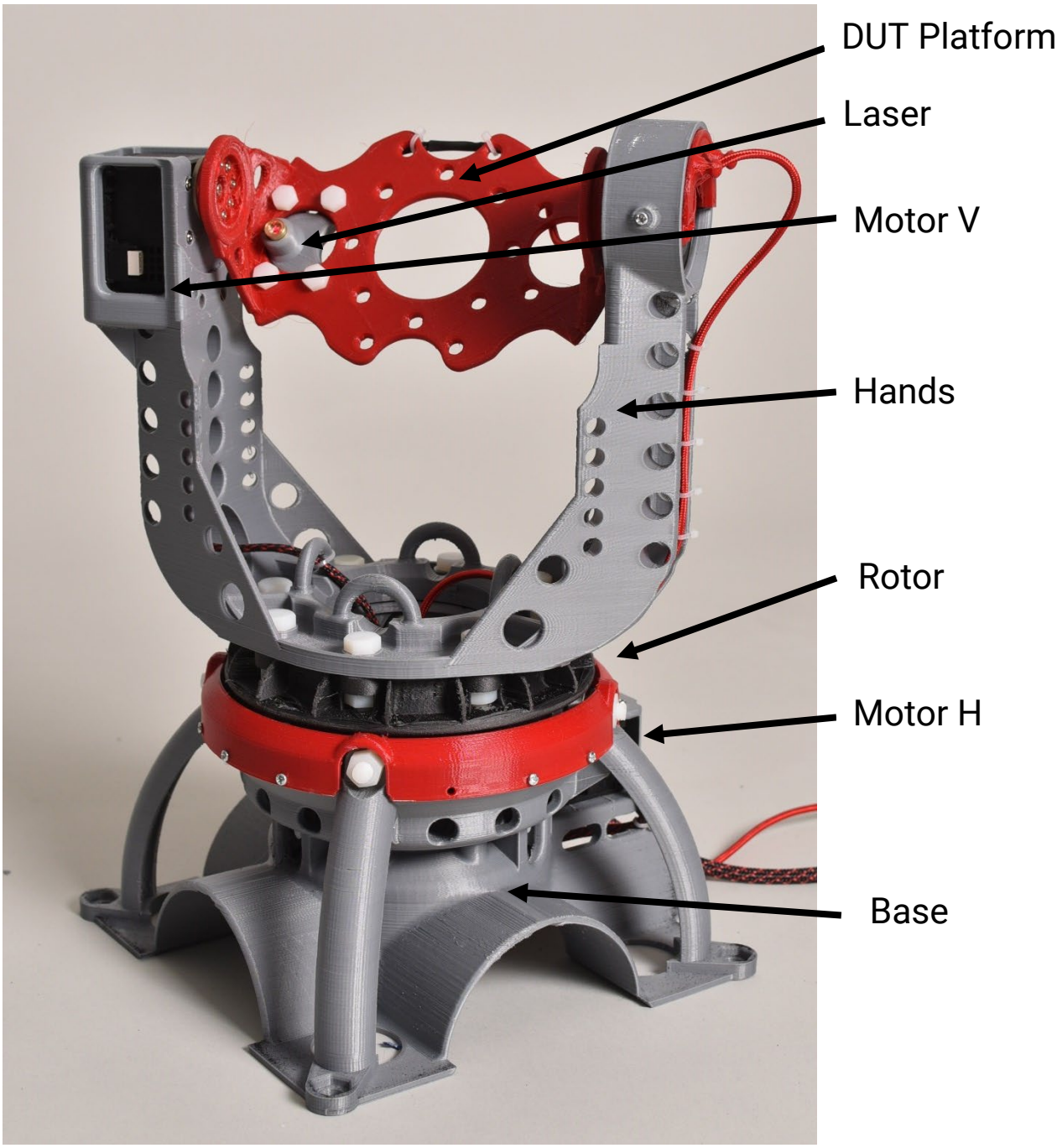
Hardware Section:

GIM01 3D positioner:

Getting to know the GIM01 3D positioner assembly:

In this manual, we use the following designation for the main parts of the 3D positioner:



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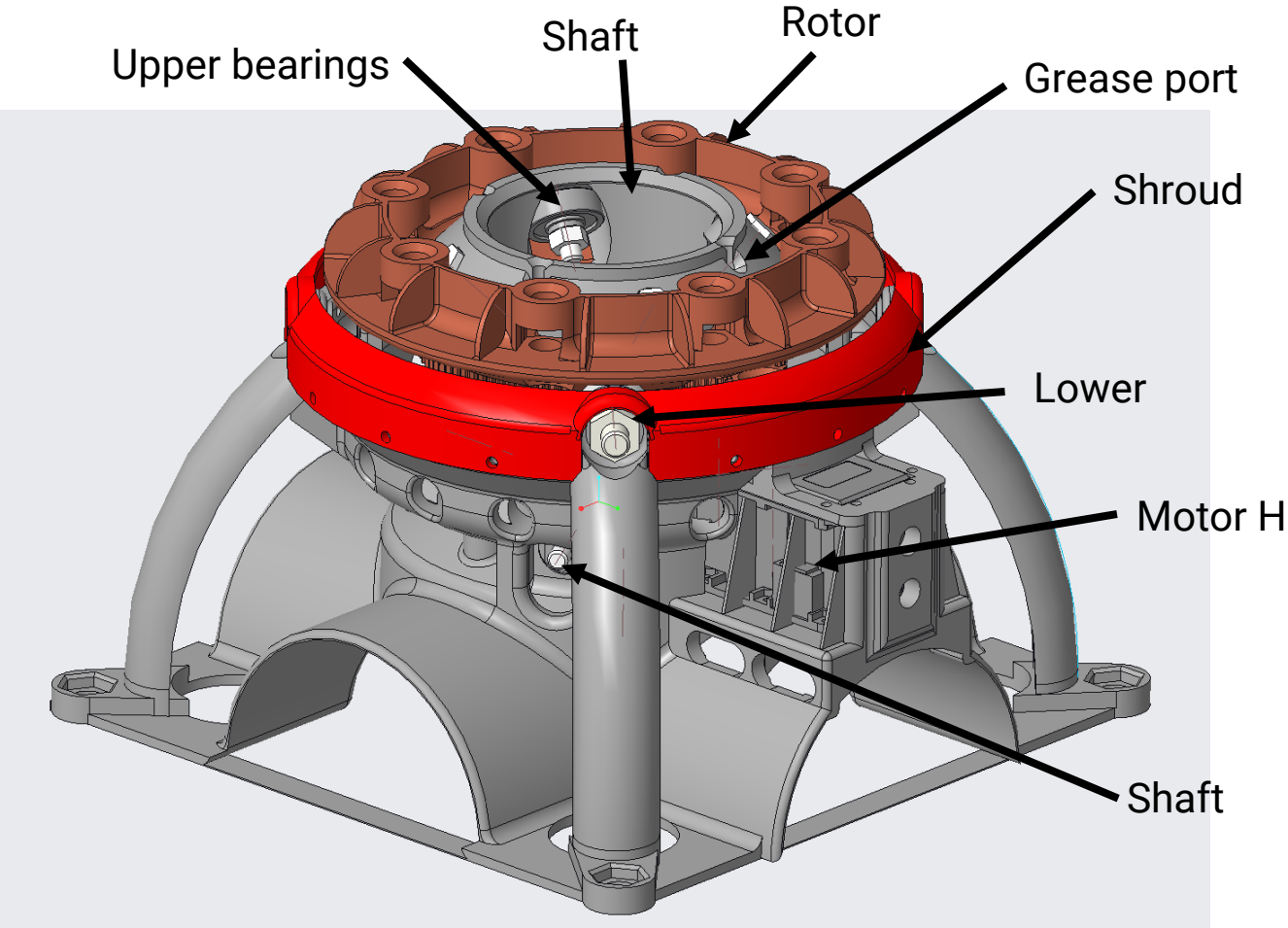
Base details:

Locate the different components constituting the Base assembly.



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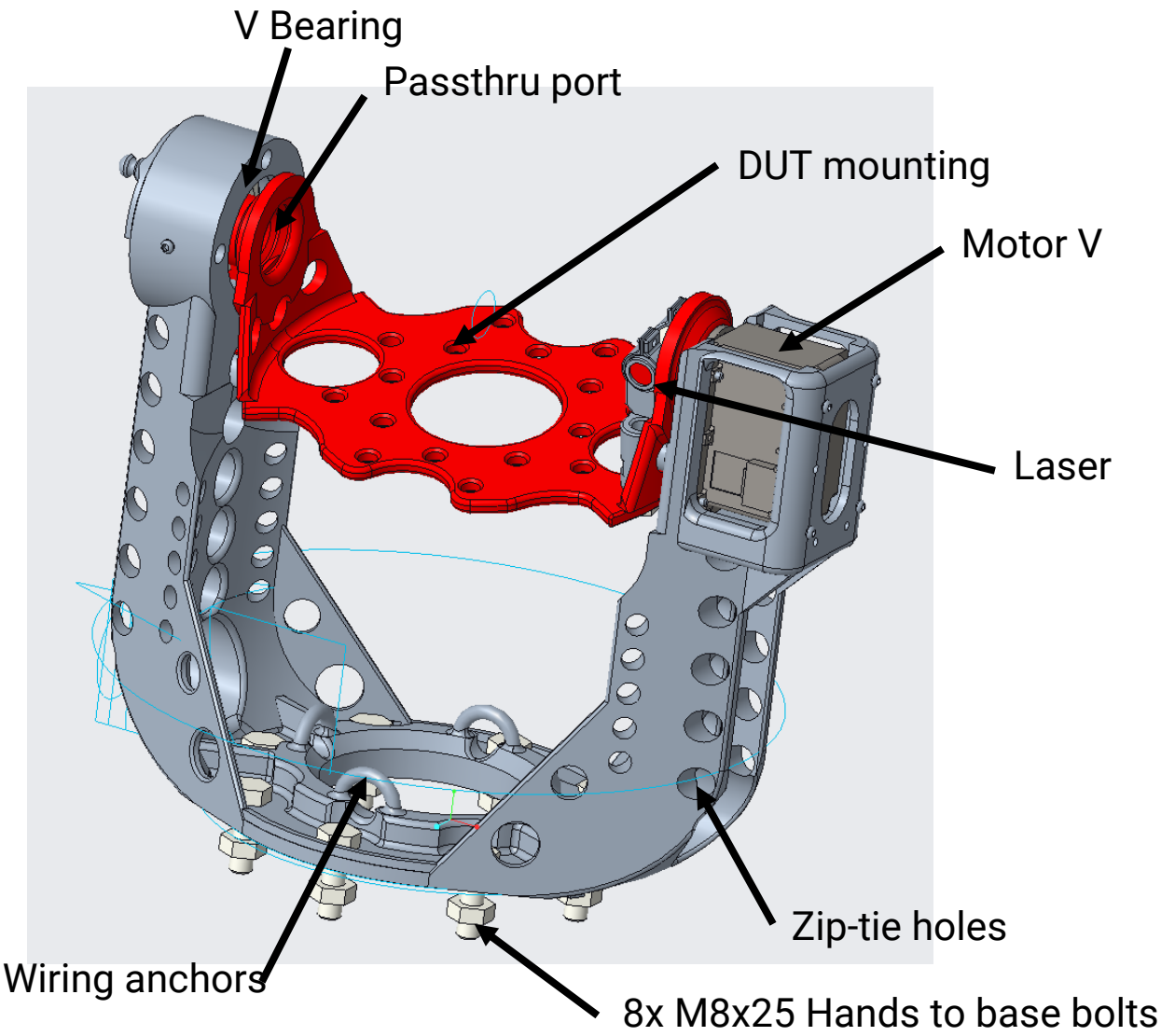
Hands details:

Locate the different components constituting the Hands assembly.



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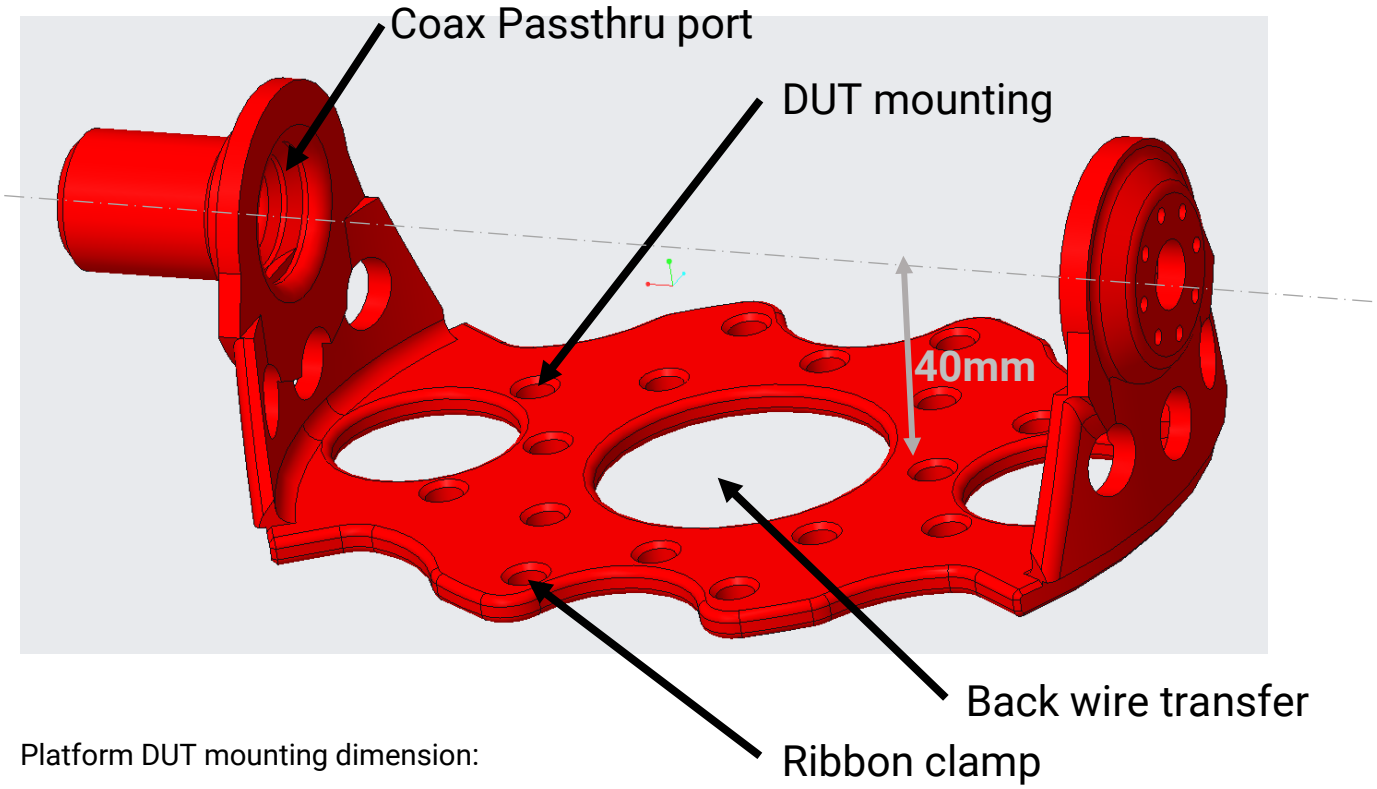
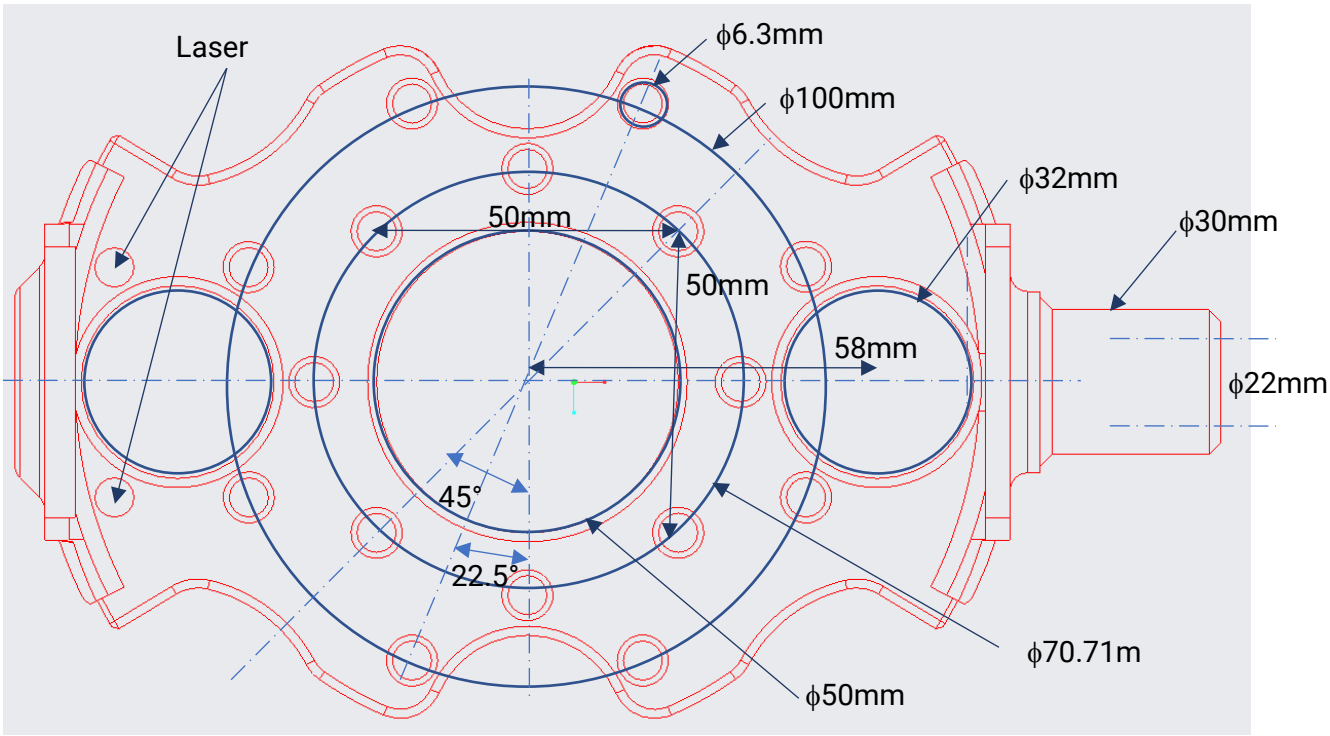
Platform details:

The platform has many features to allow great flexibility to reliably mount the DUT and route the wiring to the DUT.



Platform DUT mounting dimension:



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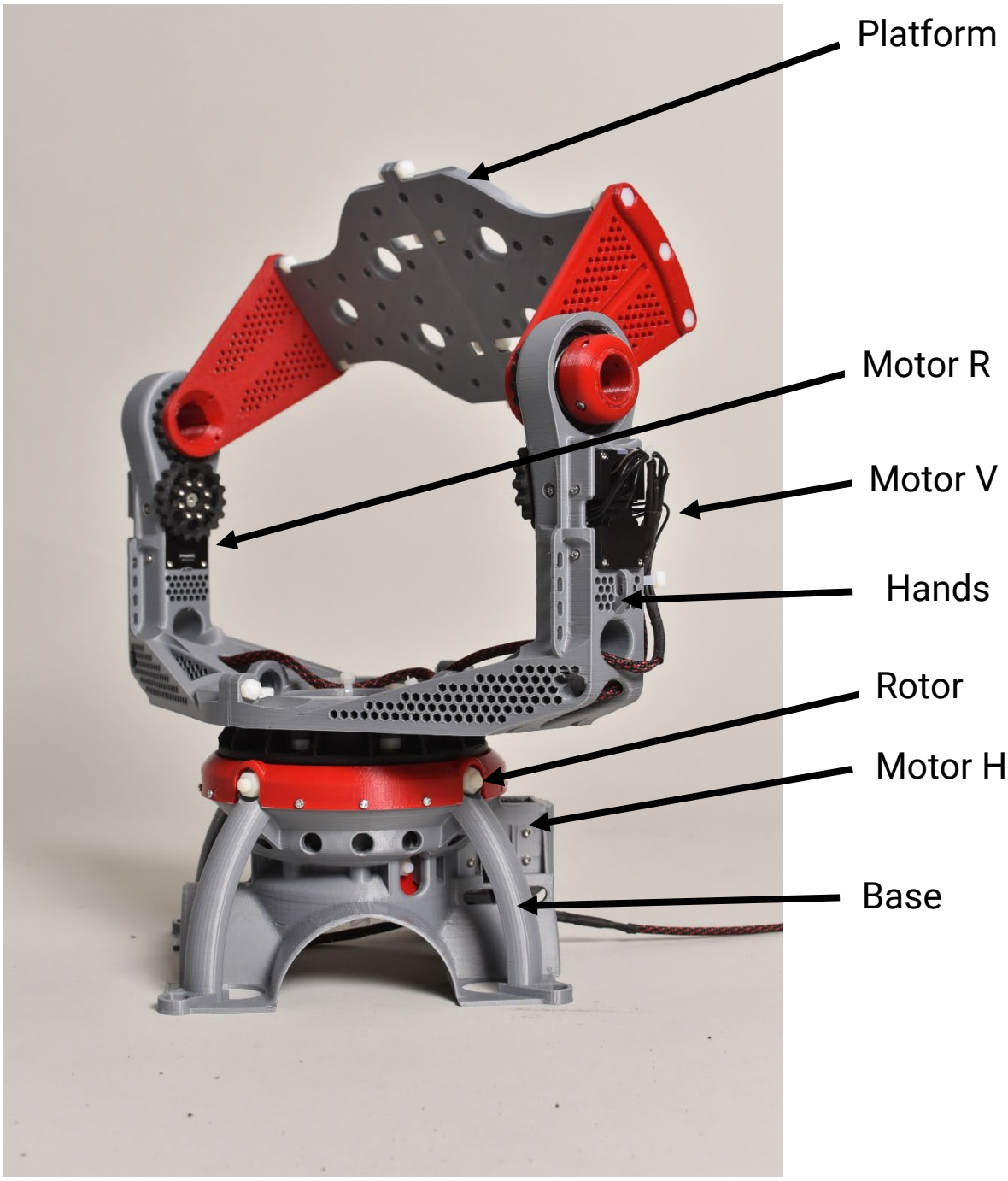
GIM03 3D positioner:

Getting to know the GIM03 3D positioner assembly:

In this manual, we use the following designation for the main parts of the 3D positioner:



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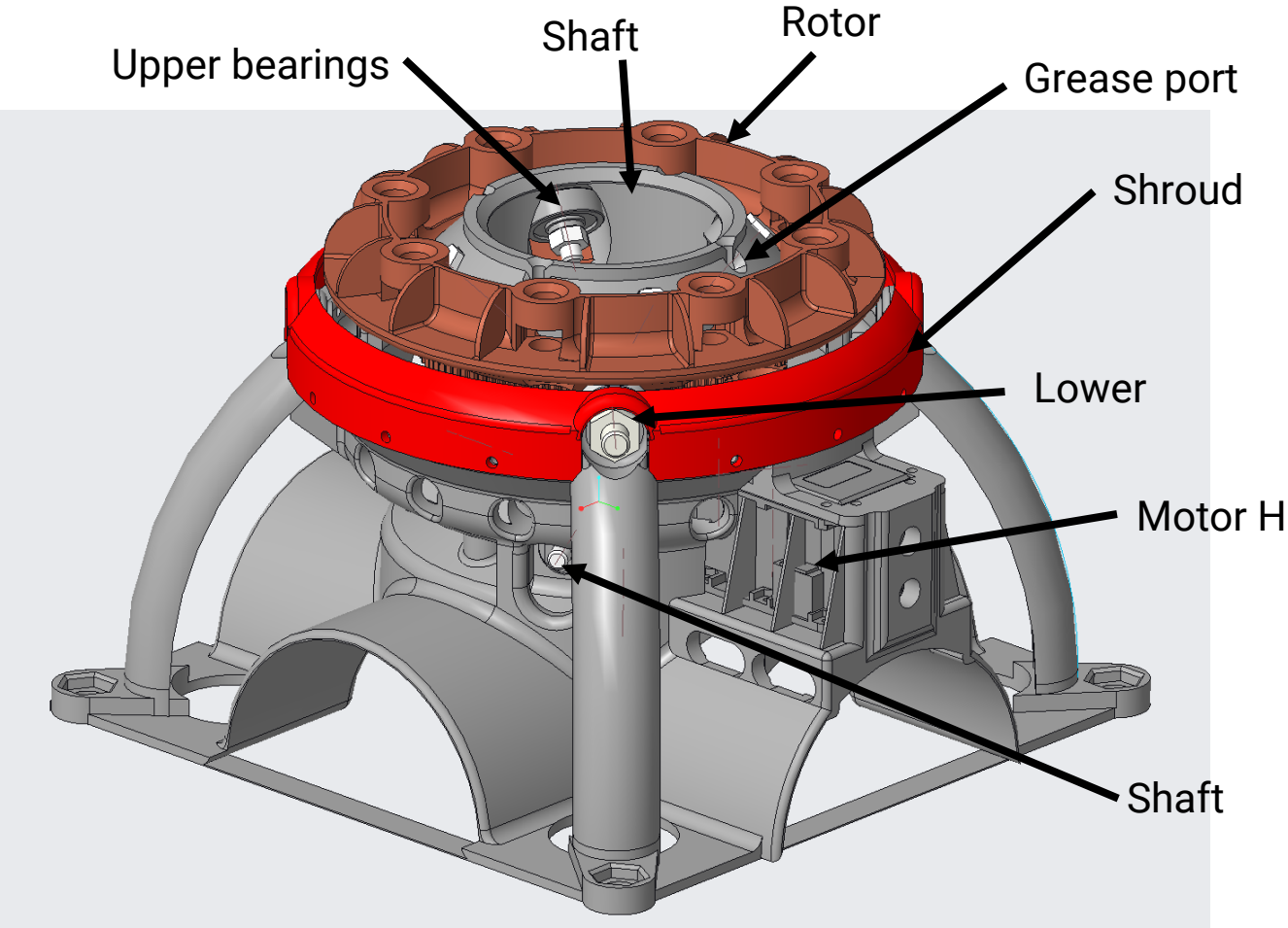
Base details:

Locate the different components constituting the GIM03 Base assembly.



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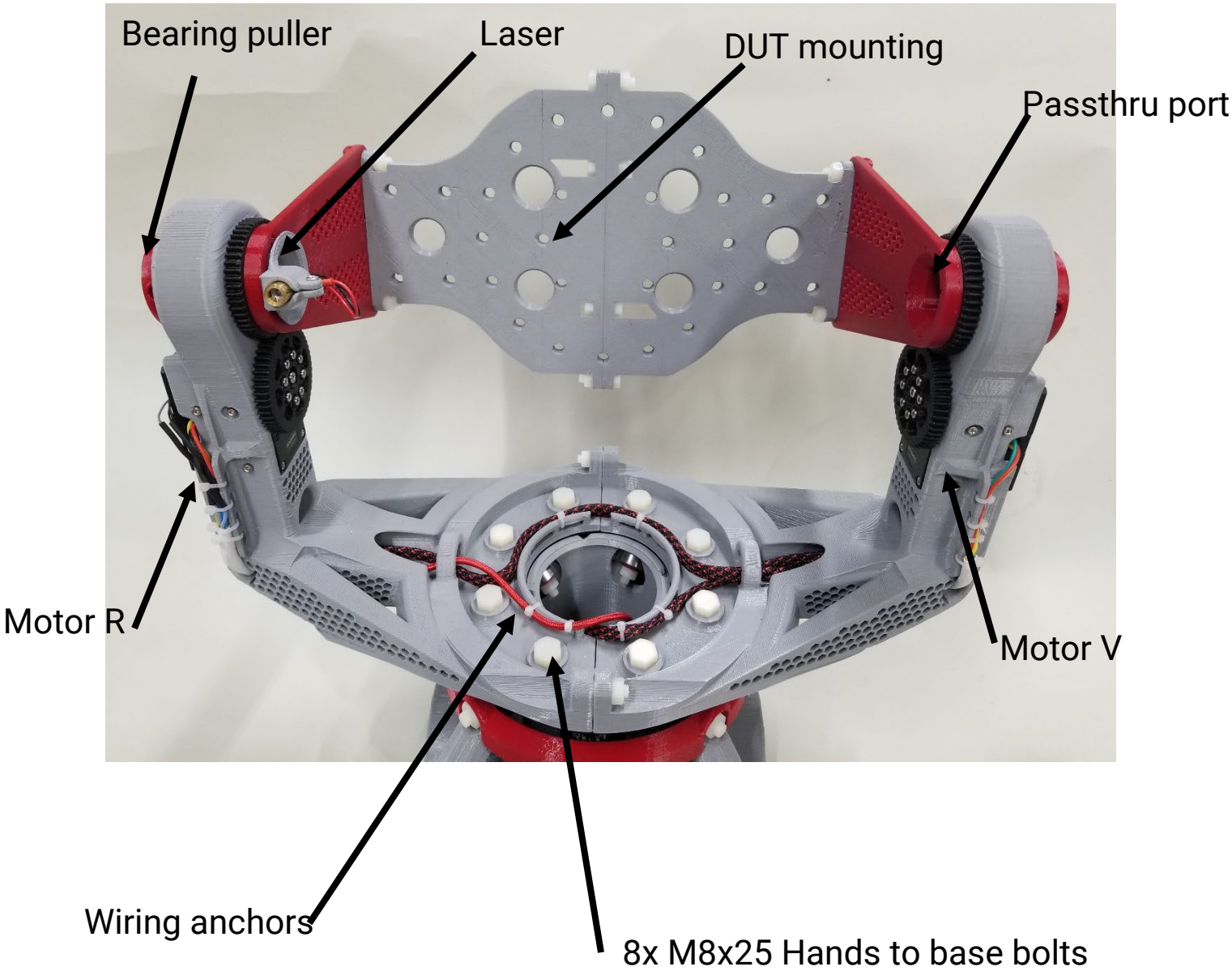
Hands details:

Locate the different components constituting the Hands assembly.



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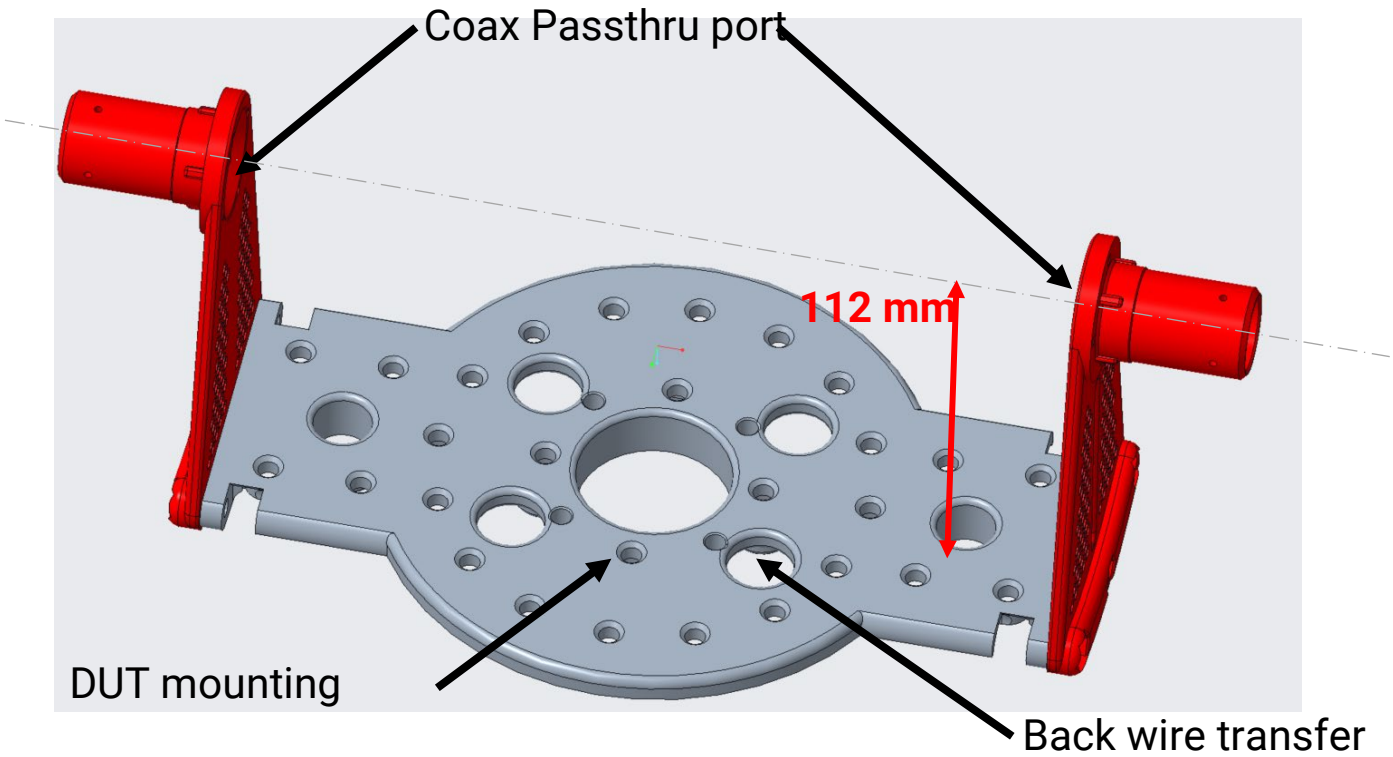
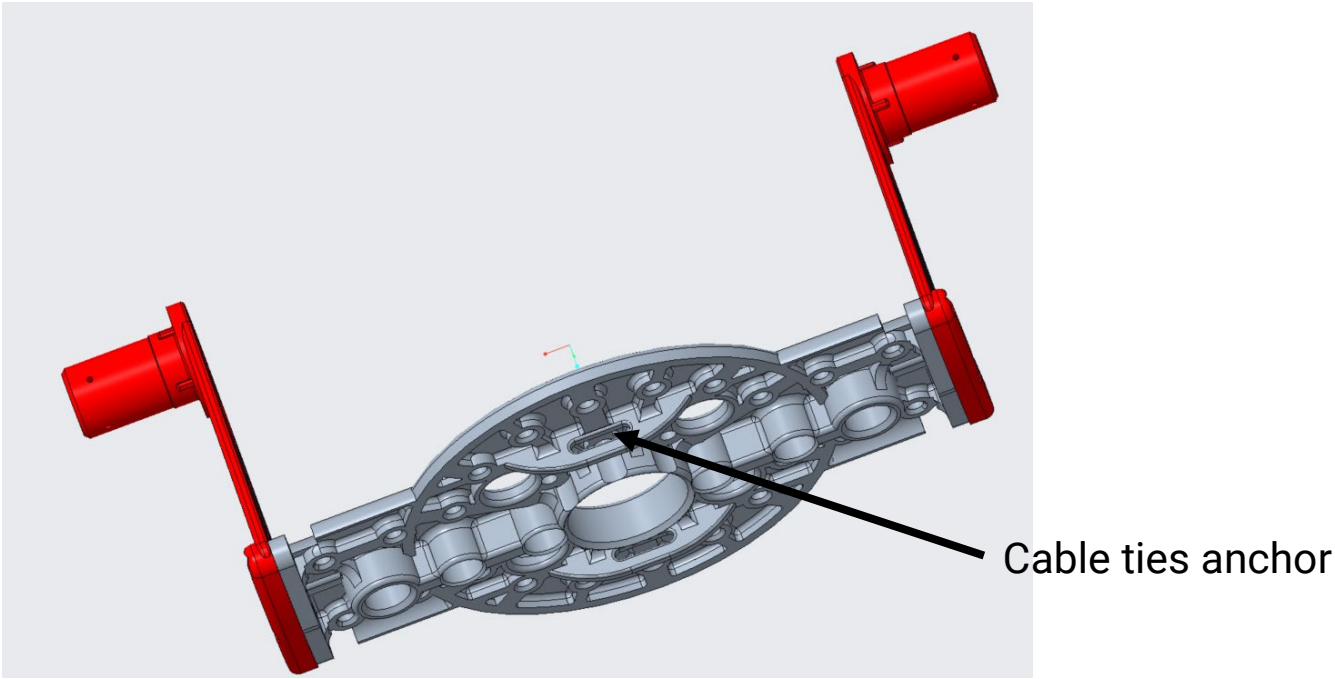
Platform details:

The platform has many features to allow great flexibility to reliably mount the DUT and route the wiring to the DUT.





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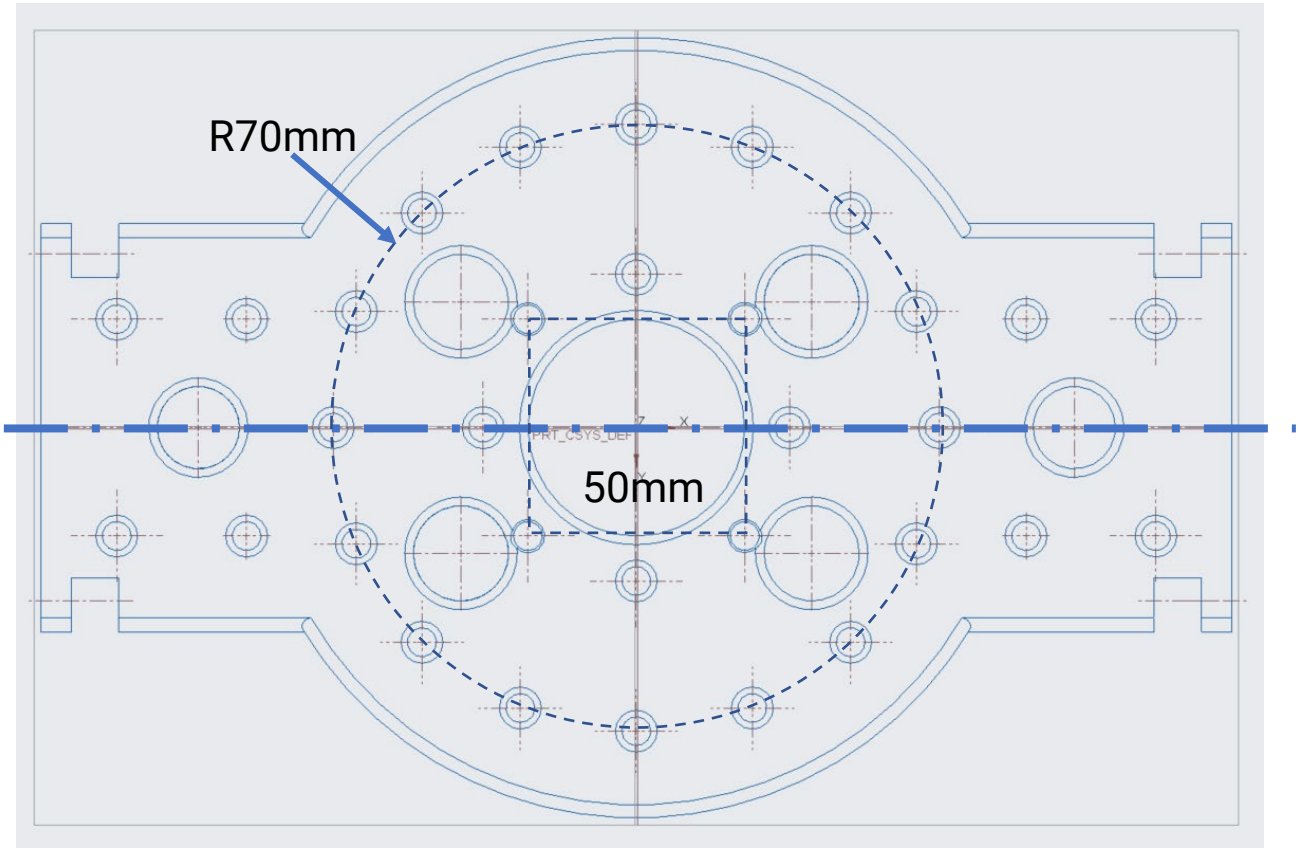
Platform DUT mounting dimensions:



All mounting holes ϕ6.5mm for ISO M6 bolts

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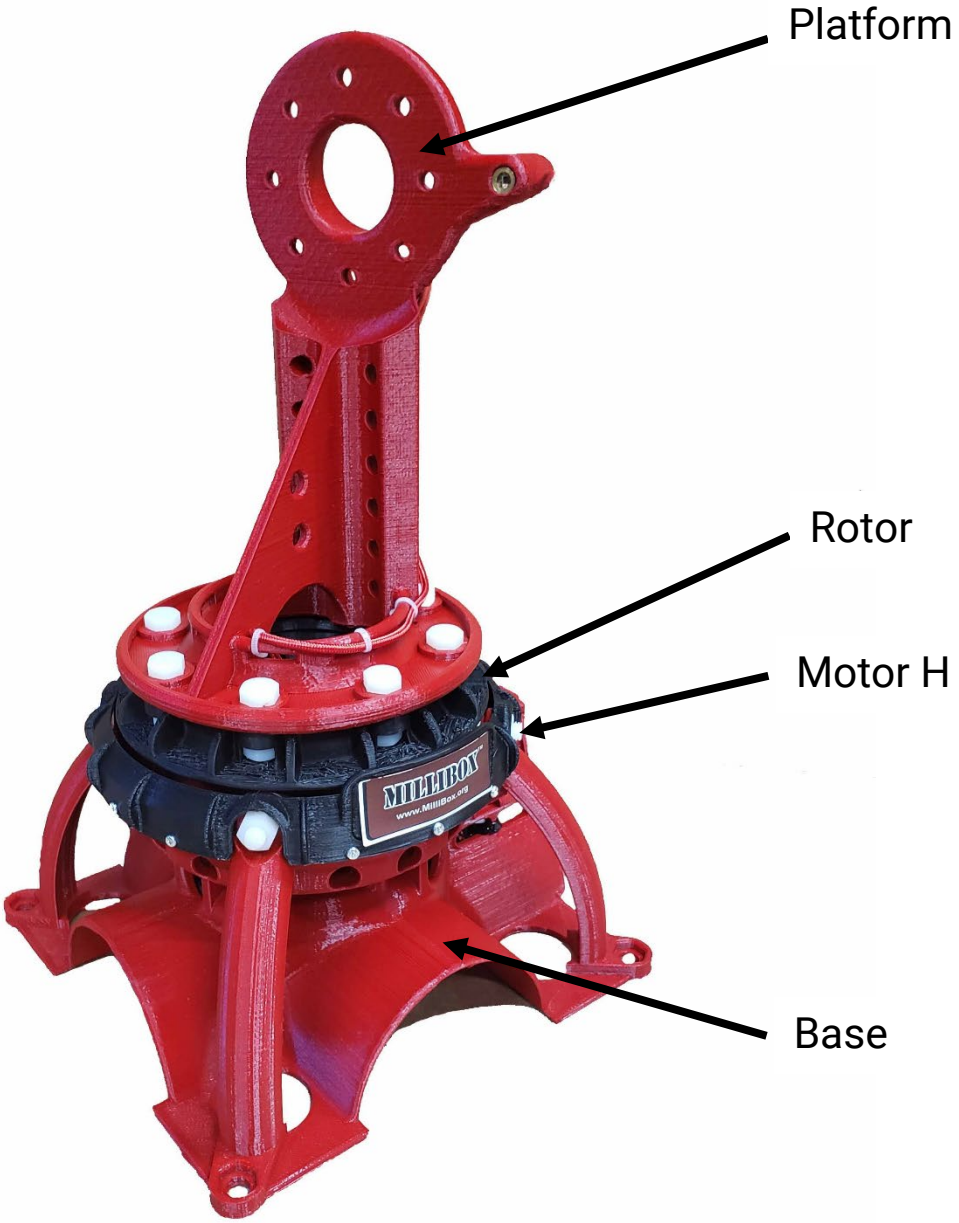
GIM1D positioner:

Getting to know the GIM1D positioner assembly:

In this manual, we use the following designation for the main parts of the positioner:



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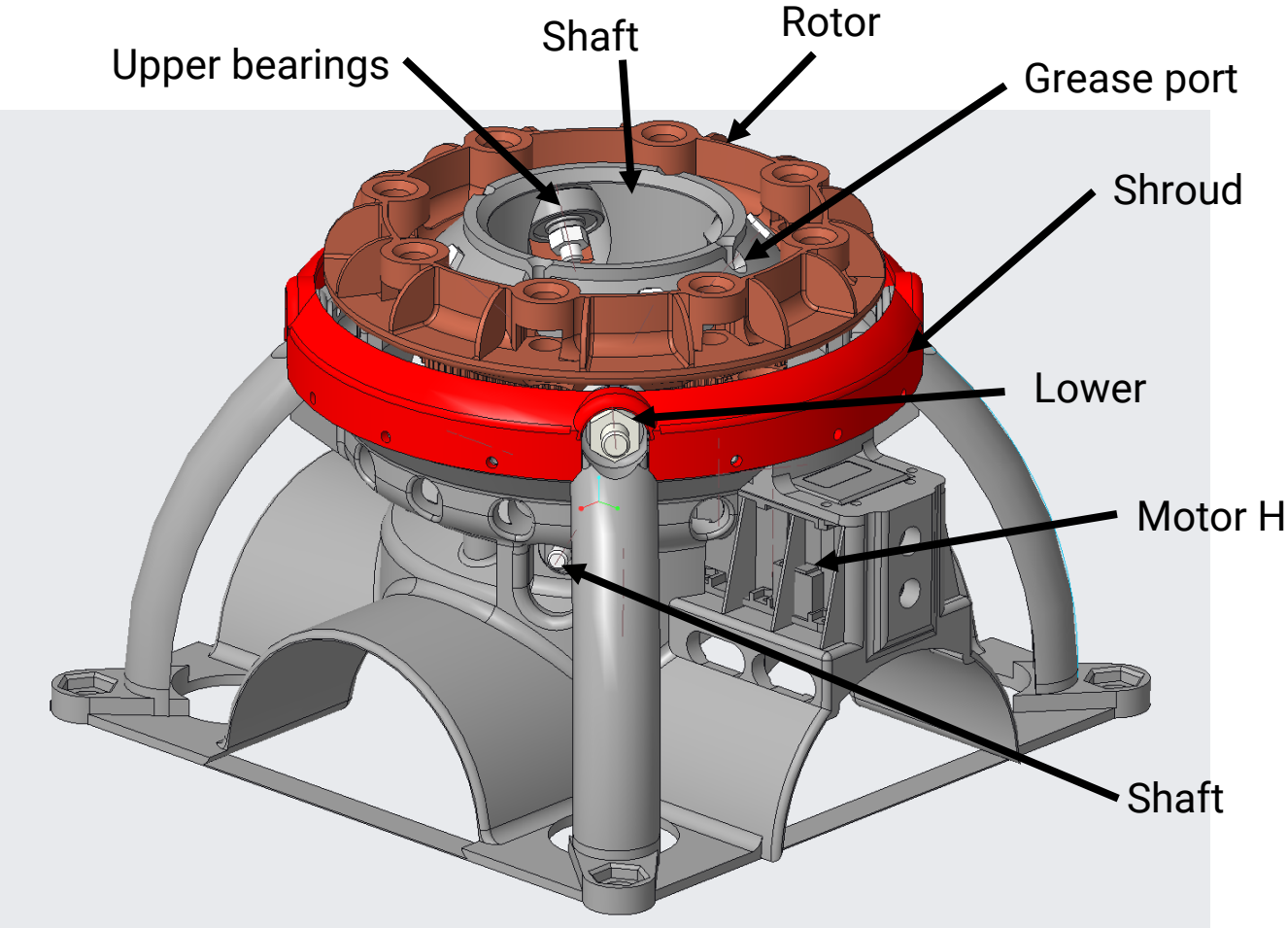
Base details:

Locate the different components constituting the GIM1D Base assembly.



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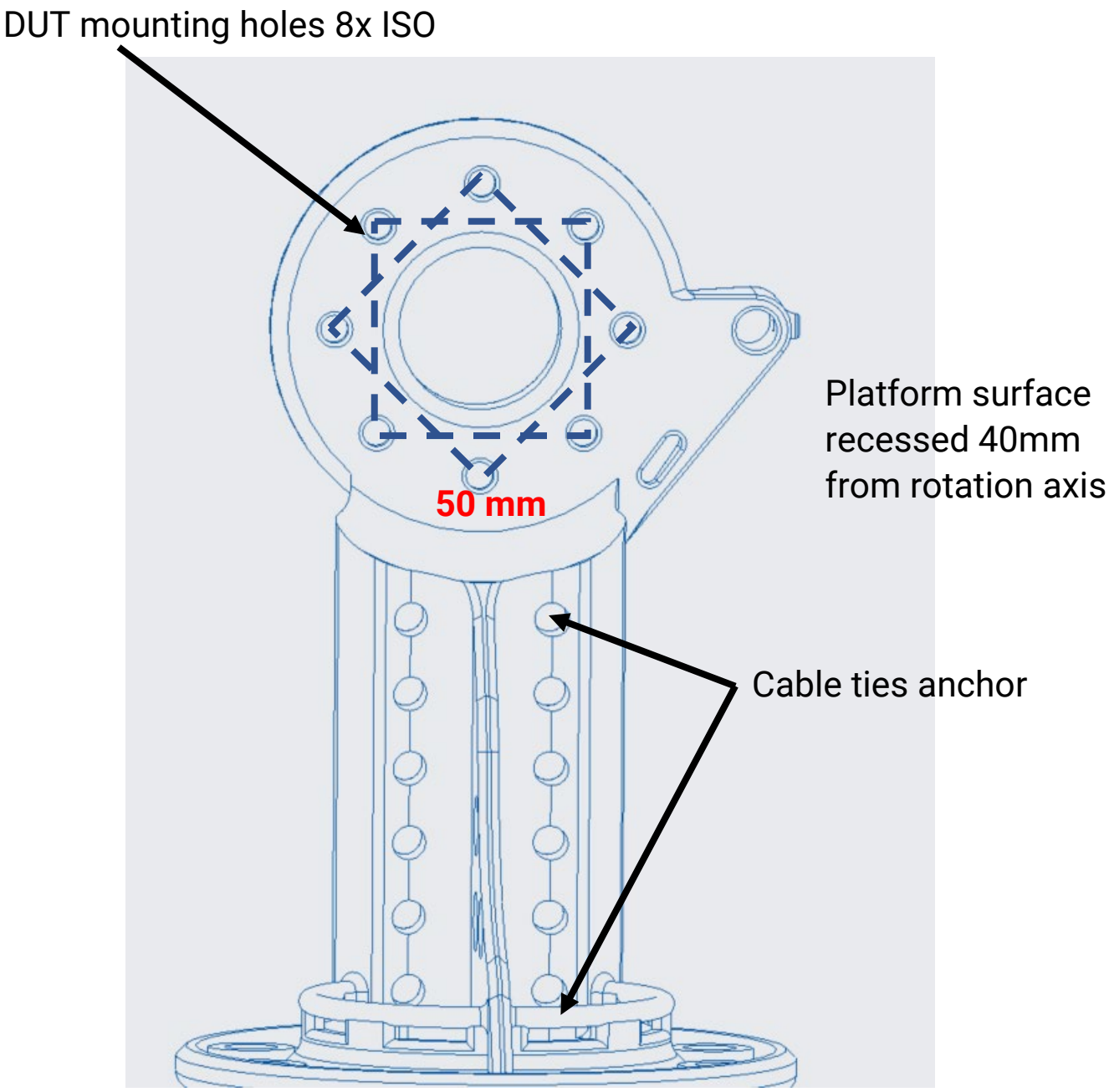
GIM1D Platform details:

The platform has many features to allow great flexibility to reliably mount the DUT and route the wiring to the DUT.



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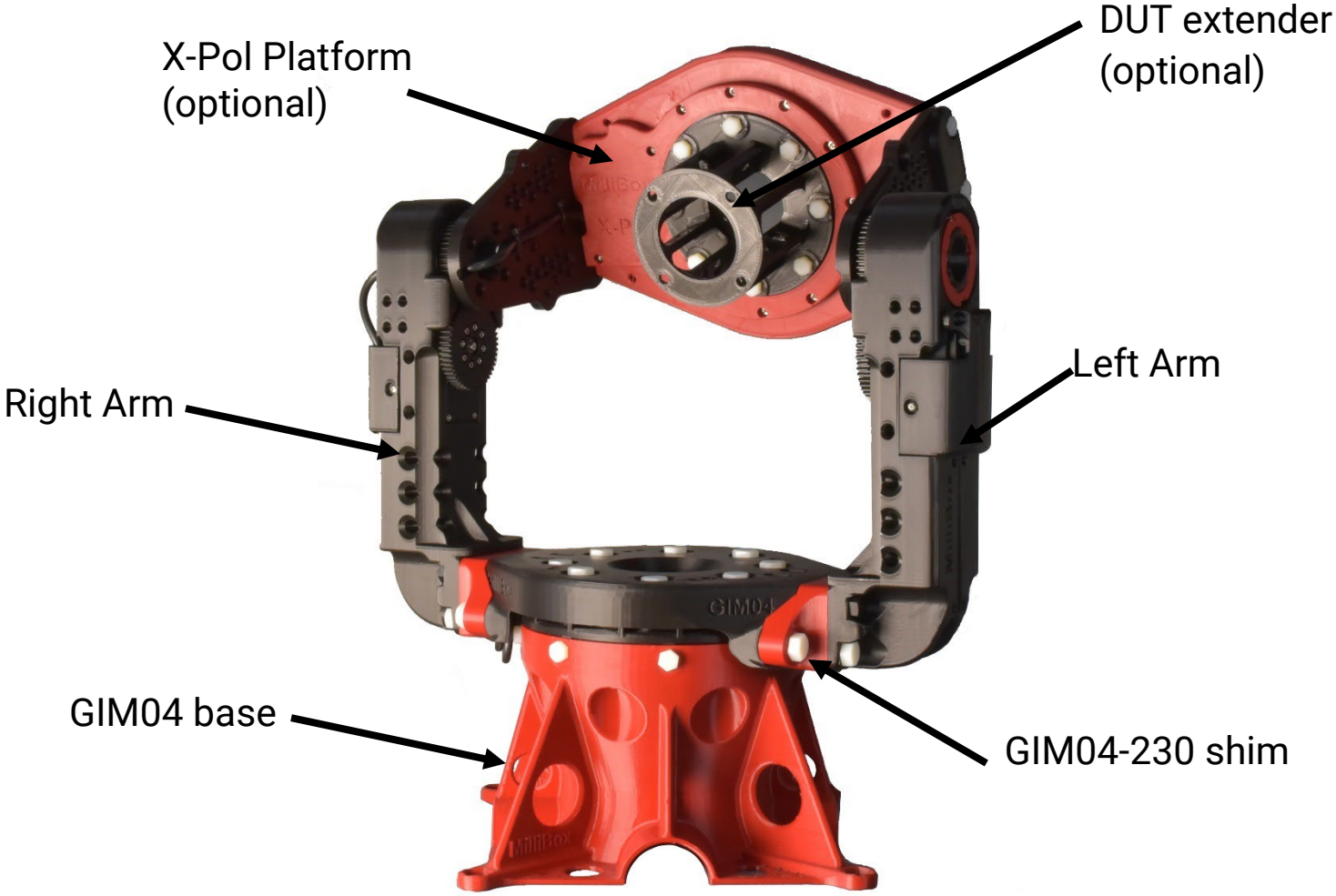
GIM04 positioner:

Getting to know the GIM04 positioner assembly:

GIM04 is a modular positioner system which has many built in features and modularity.



The X-Pol platform is an optional platform available for GIM04-230, GIM04-300 and GIM04-380 and allows for control of the polarization of the Device under test.
The DUT extender is an optional raiser for the Device under test which brings the DUT mount plane at 40mm from rotation axis.
The right and left arms are symmetrical. The right arm holds Motor V controlling the elevation position and has the control harness for X-Pol. The Left arm has Motor R which is slave mirror from motor V to control elevation. And hold the laser crosshair pointer.
The GIM04 base is a new base from all other GIM0x positioners. It holds a new type of motor H which controls the positioner's azimuth position.

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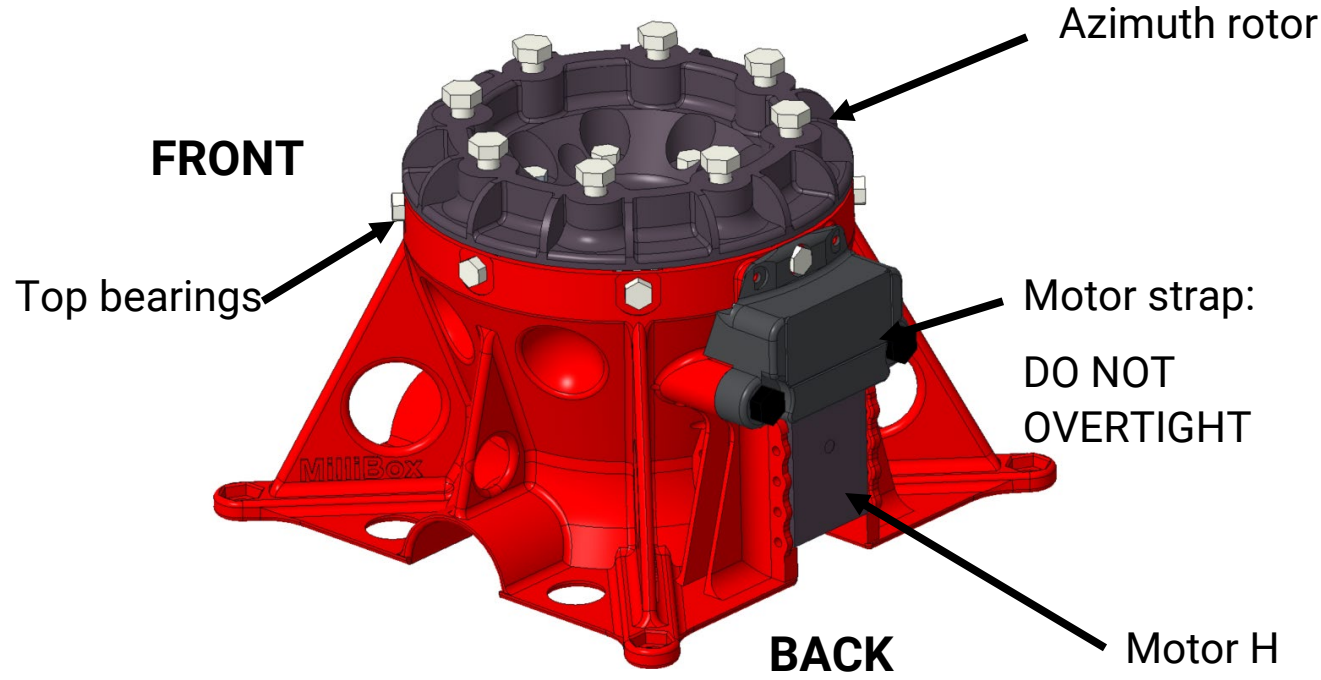
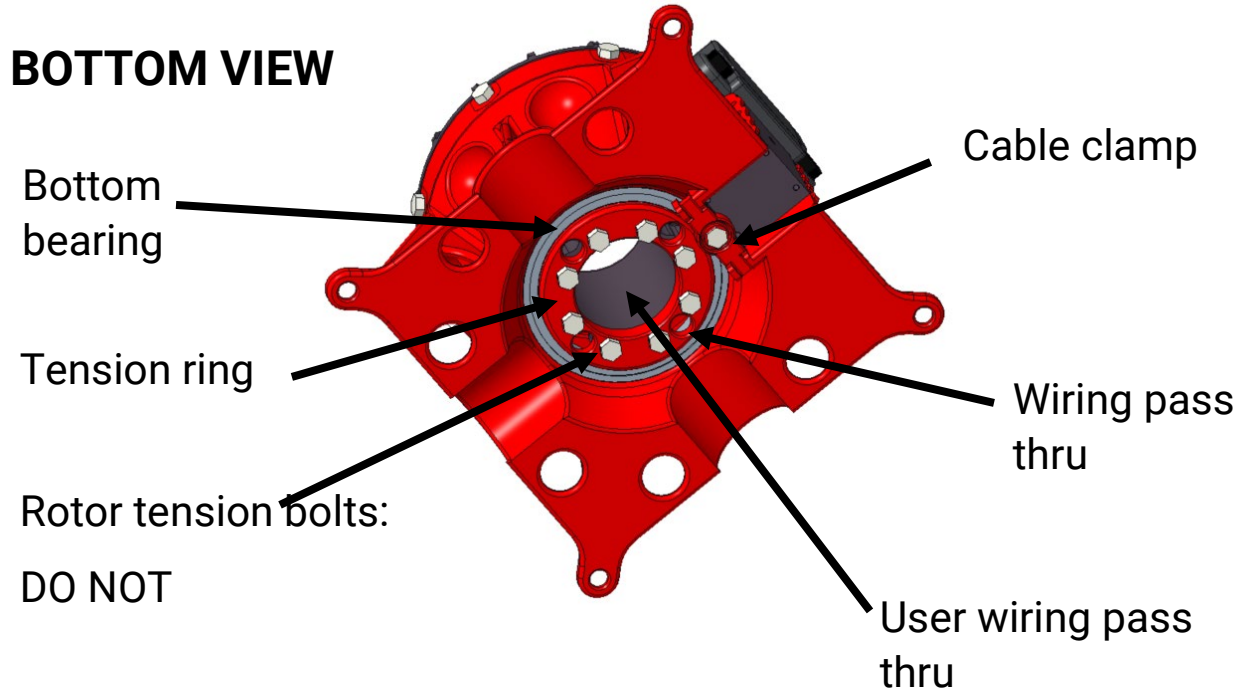
The GIM04 shims are sets of mechanical spacers which allow for the assembly of GIM04 of different widths. The standard widths are 200mm, 230mm, 300mm and 380mm.
GIM04 wiring is mainly run within the body of the positioner.

Base details:

Locate the different components constituting the GIM04 Base assembly.





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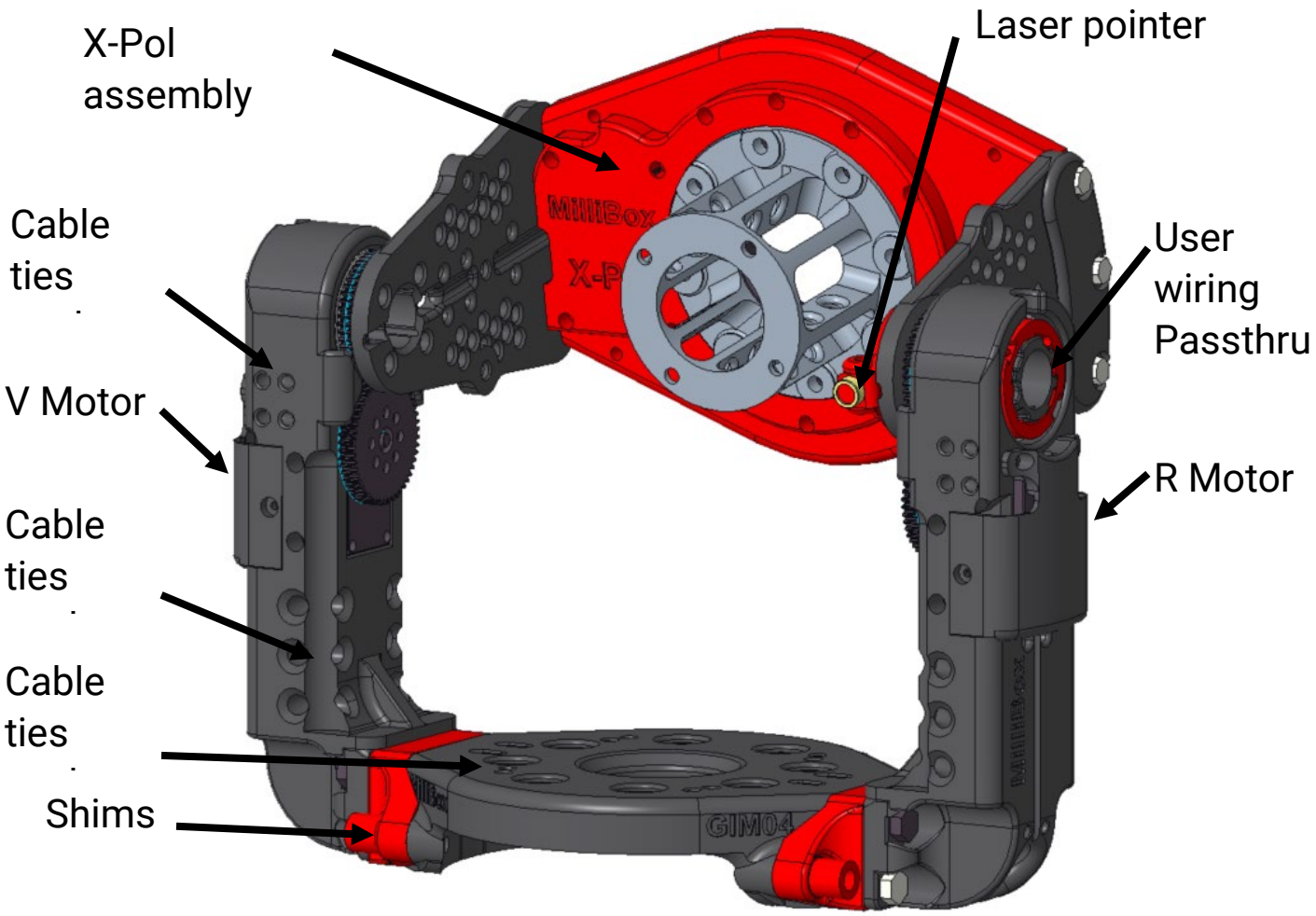
Hands details:

Locate the different components constituting the Hands assembly.



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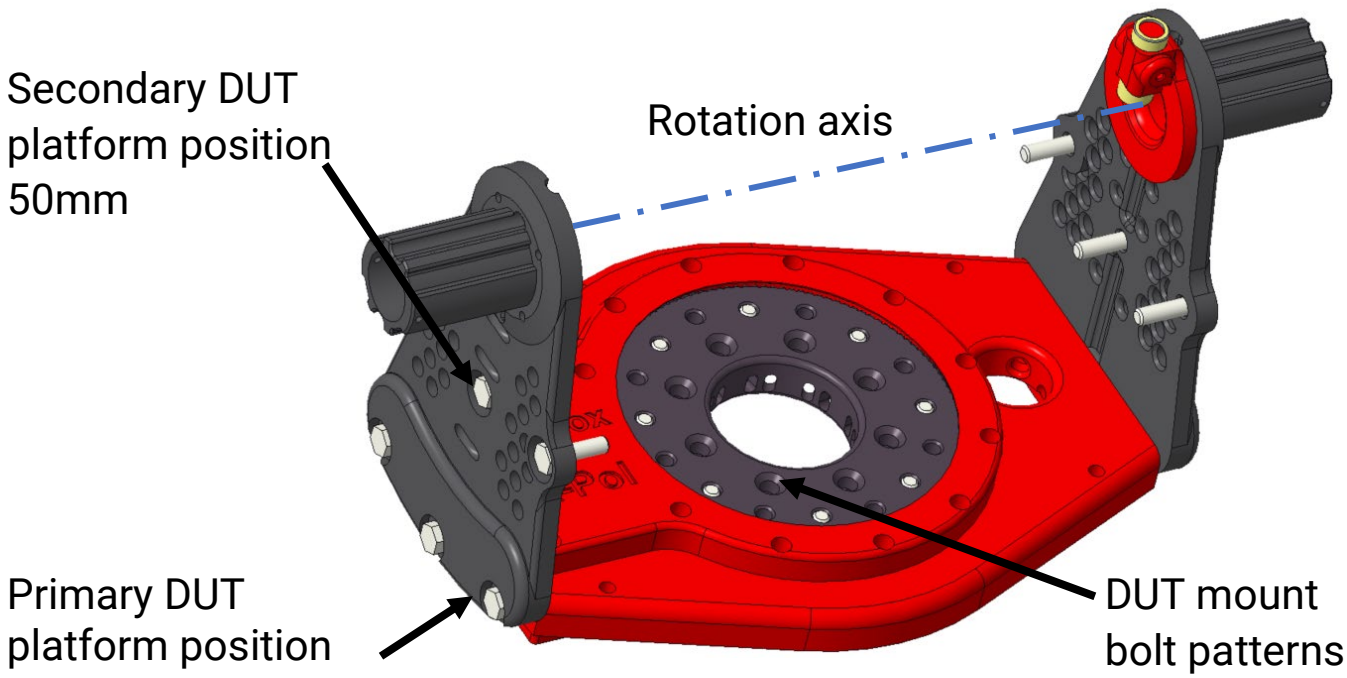
Platform details:

The platform has many features to allow great flexibility to reliably mount the DUT and route the wiring to the DUT.
There is a secondary mount position for the X-Pol DUT platform closer to the rotation axis for DUTs that are not too thick.



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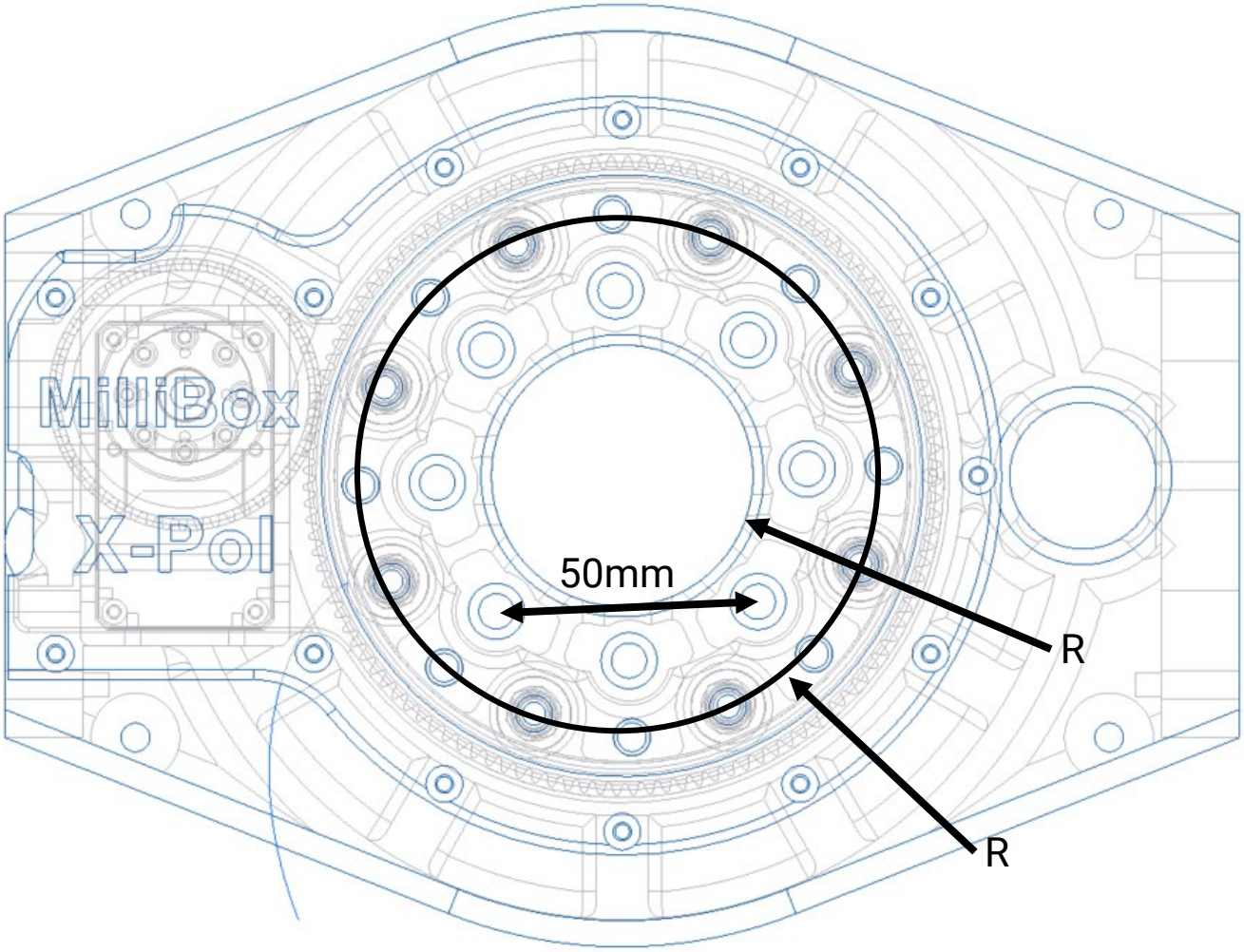
X-Pol Platform DUT mounting dimensions:



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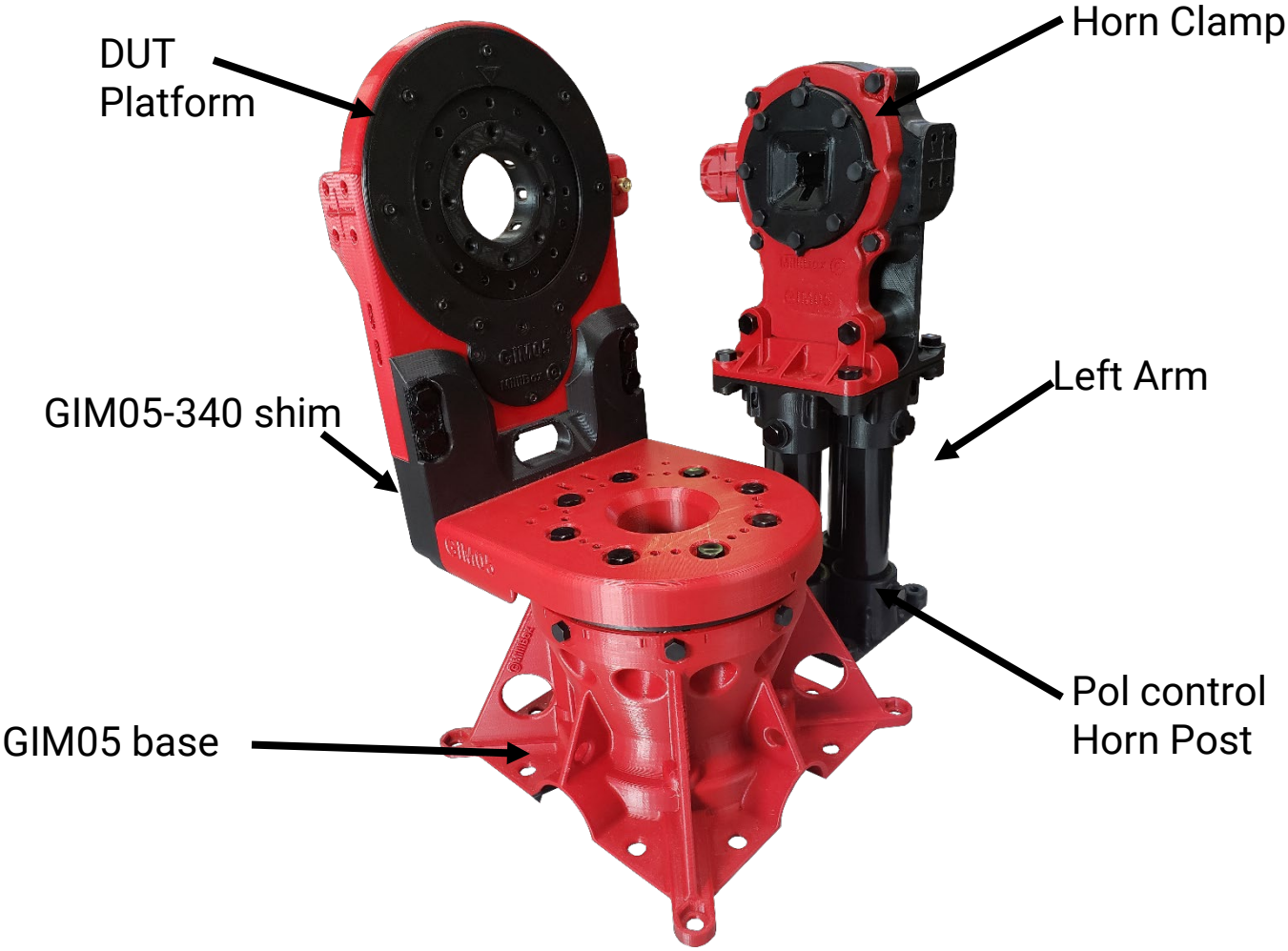
GIM05 positioner:

Getting to know the GIM05 positioner assembly:

GIM05 is a Spherical Roll positioner system working with a motorized polarization controlled horn post.



The DUT platform is recessed from the vertical rotation axis to provide ample room to mount the DUT. The platform itself rotates on its axis. The DUT mount should be designed such that the boresight radiation axis is aligned with the DUT platform rotation axis and that the vertical axis should be tangent with radiating element aperture.
The GIM05 base is a new base from all other GIM0x positioners. It is compatible and interchangeable with GIM04 base mechanically but uses a different motor type.
The GIM05 shim is a mechanical piece which allows the creation of many variations of size and capacity from the fundamental features. MilliBox offers 2 standard variations for it, one to create GIM05-340 ideal for MBX0x chamber size and GIM05-440 ideal for MBX3x chamber sizes.

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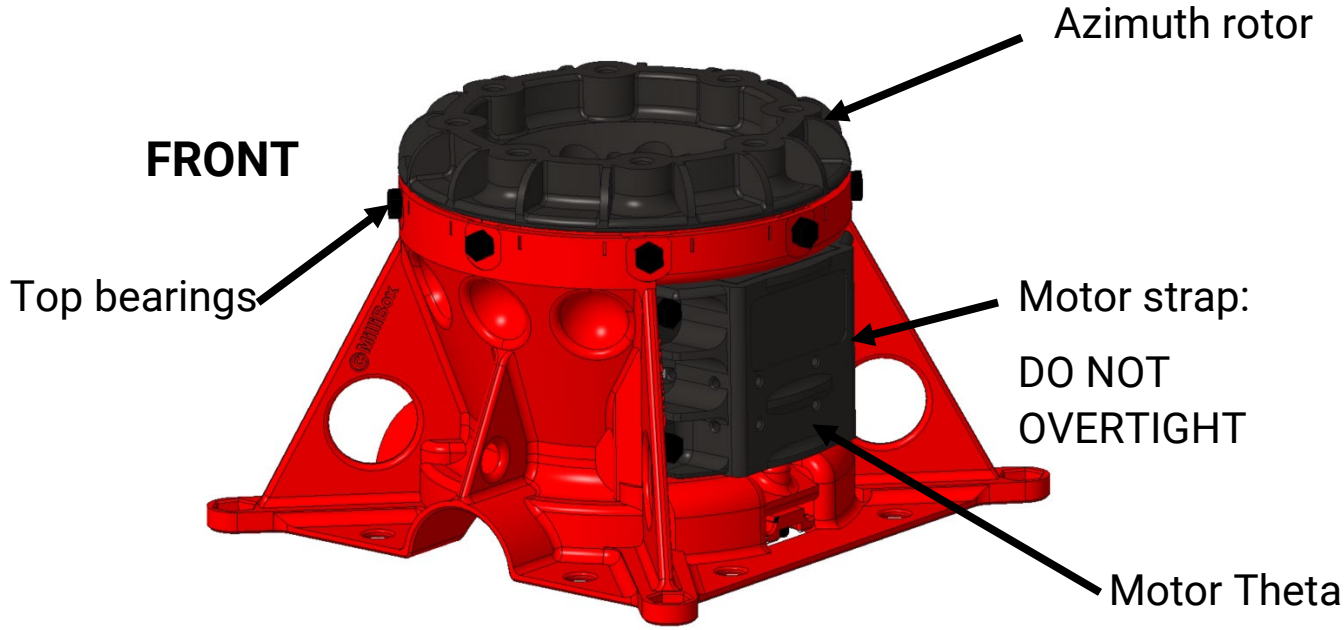
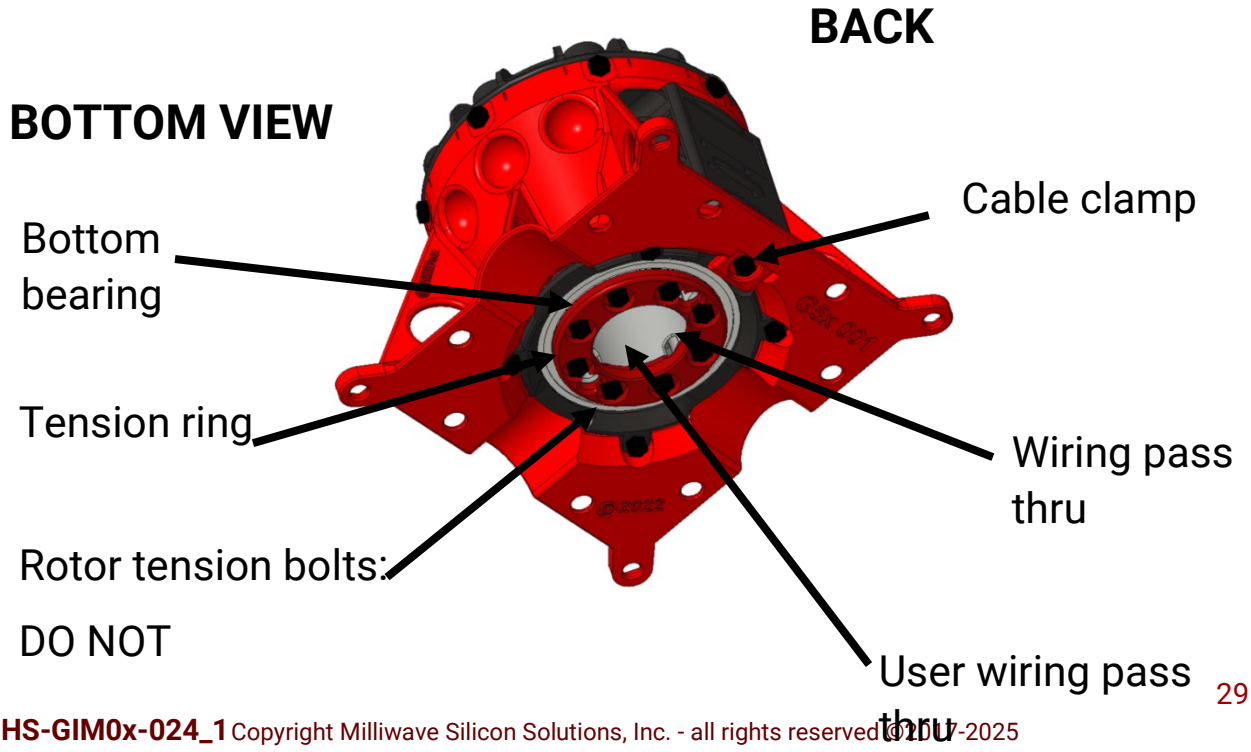
The GIM05 Horn post is a motorized Horn Post, which matches the height of the GIM05 and allows the probe to rotate on its radiation axis in a synchronized fashion with the DUT platform. The horn post probe can be programmed to be polarized matched with the DUT or at any given angular offset from it.

Base details:

Locate the different components constituting the GIM05 Base assembly.





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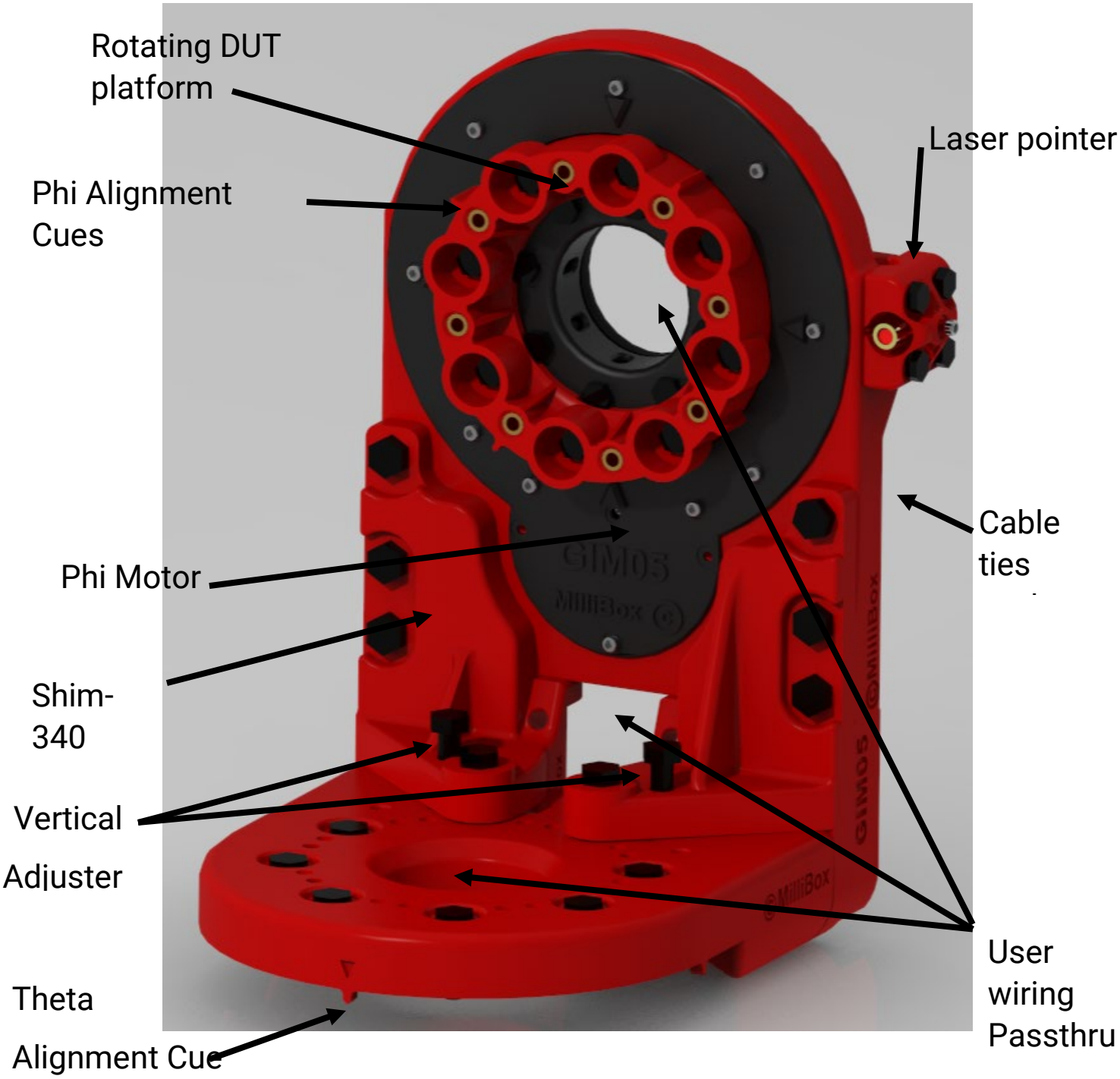
Hand details:

Locate the different component constituting the Hand assembly.



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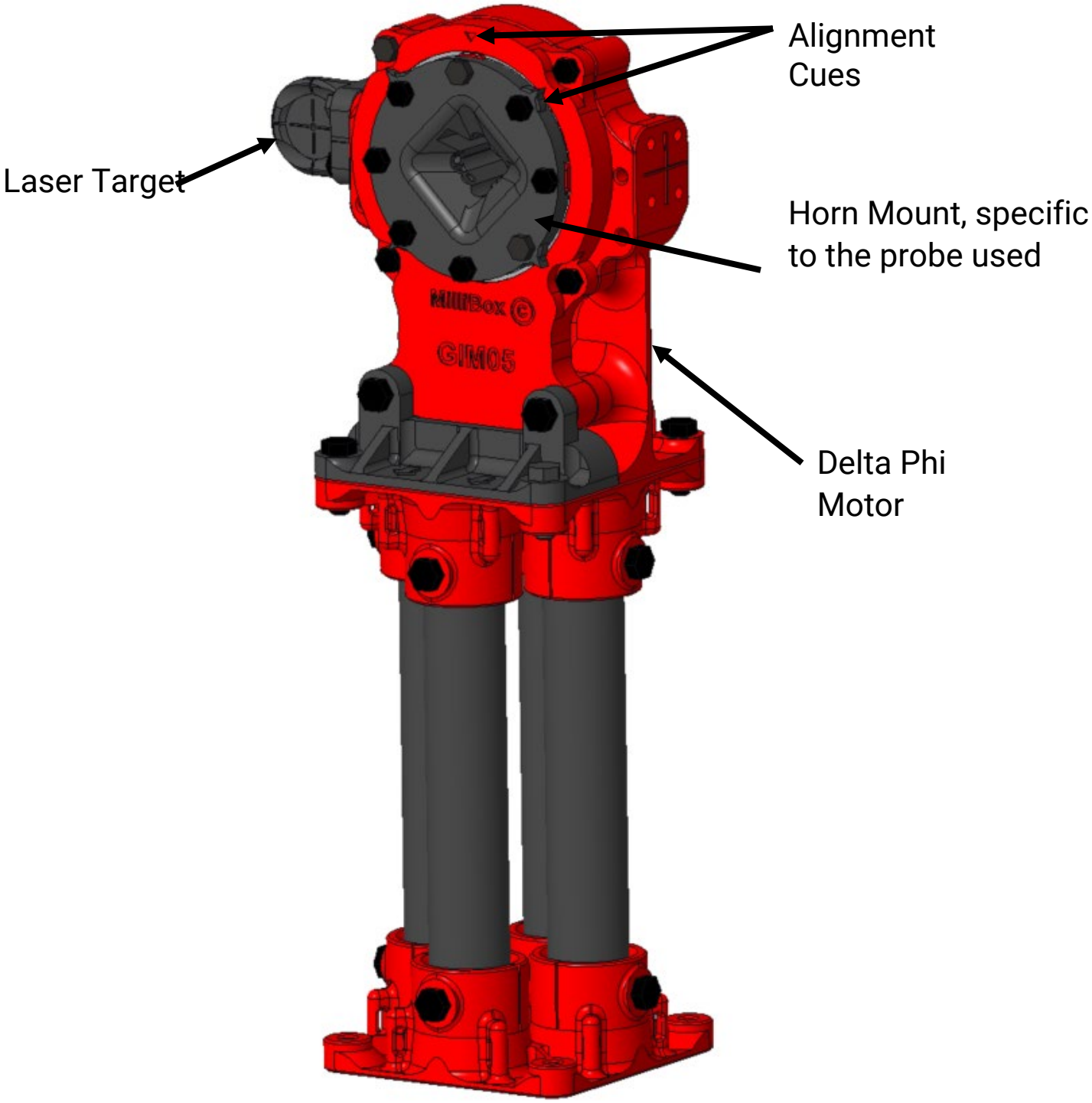
Horn Post details:

The motorized Horn Post is an integral part of the GIM05 system. It can accommodate various Horn Antenna standards.



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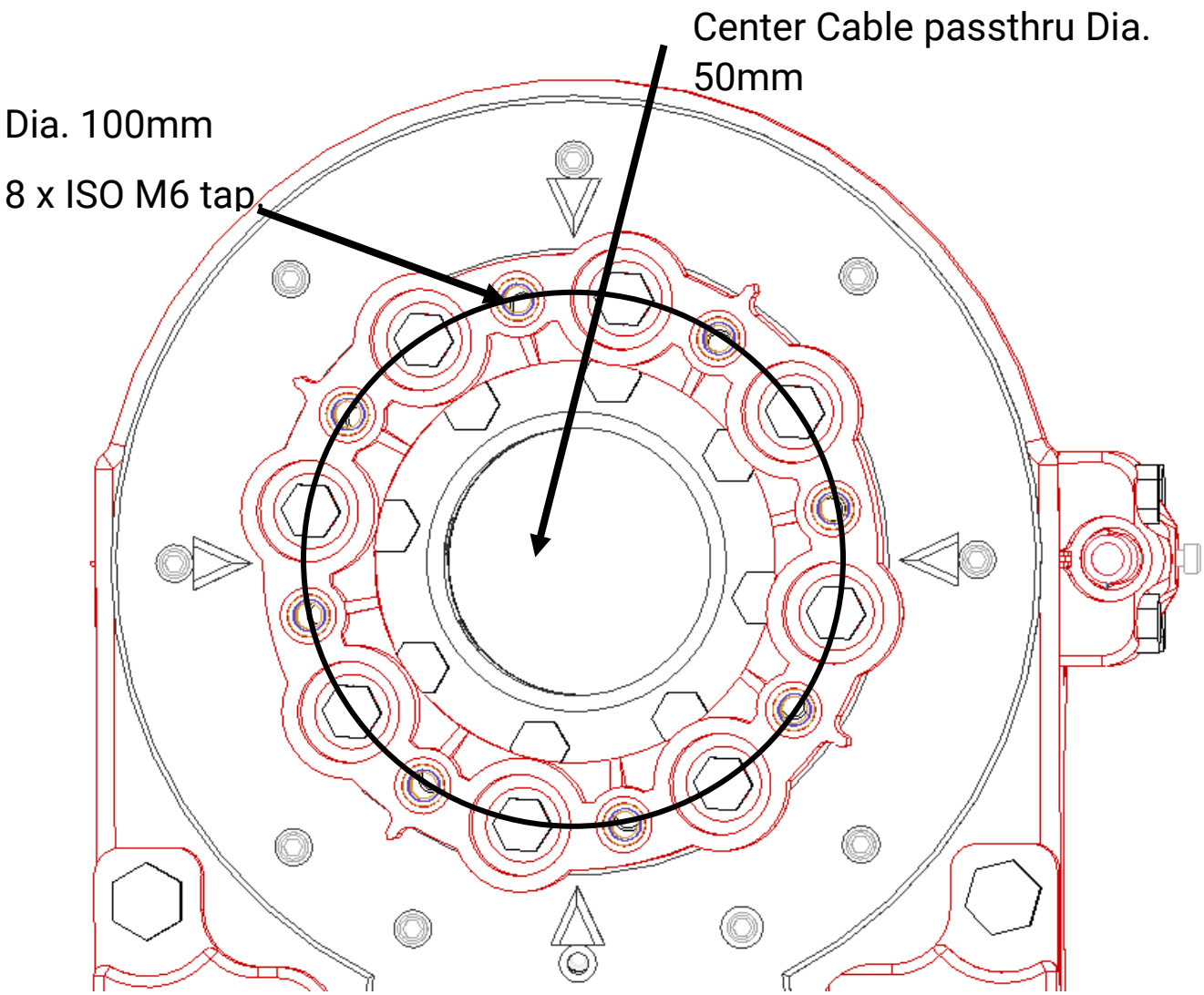
GIM05 Platform DUT mounting dimensions:



The distance from the DUT platform to the vertical rotation axis for GIM05_340 is **87mm**
The distance from the DUT platform to the vertical rotation axis for GIM05_440 is **147mm**

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GIM05 Vertical Adjustment:

To accommodate various DUT weight and keep the DUT boresight aligned with the Probe post, GIM05-340 and GIM05-440 is equipped with a Vertical adjuster mechanism which can go down 1deg and up 2 deg,
The front of the square brackets holding the DUT platform to the Gimbal deck has counteracting bolts:

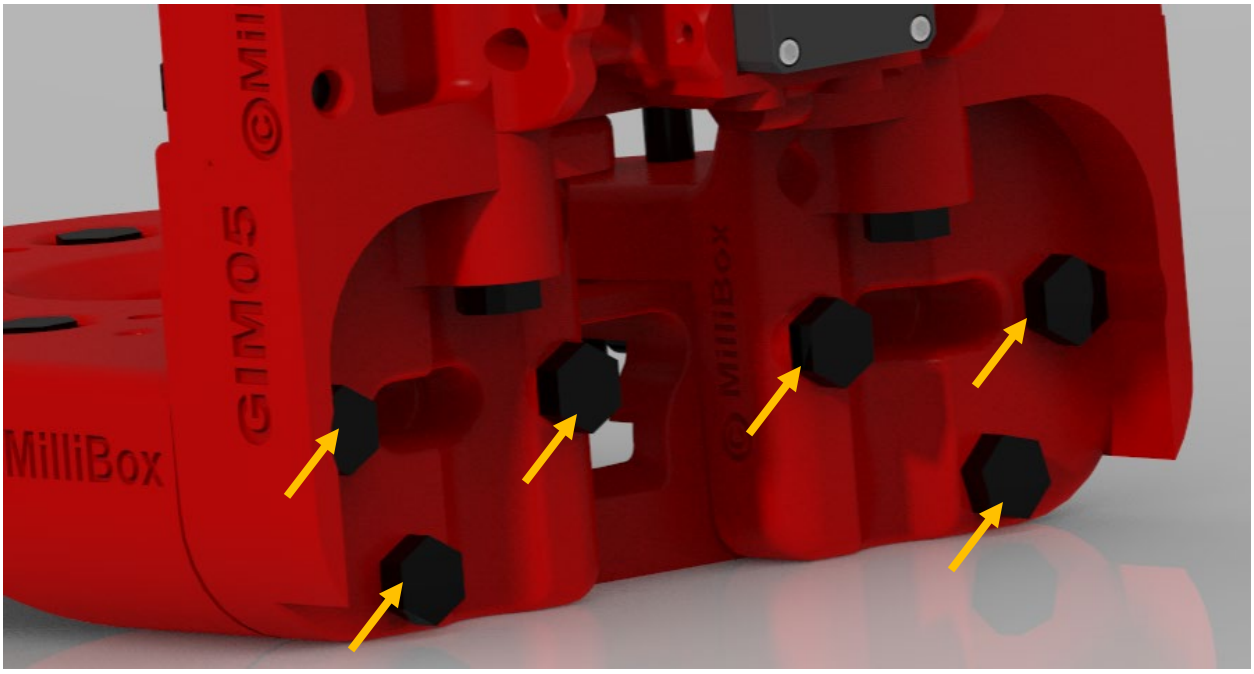
- Screwing down the Lowering Bolt makes the DUT tilt down.
- Screwing down the Raising Bolt makes the DUT tilt up.

Since those bolts are counteracting, you must unscrew one direction the same amount that you screw the other one to get the alignment perfect. Screwing one bolt without unscrewing the other will break the bracket.

You must loosen the 6 bolts by at least 3 turns in the back before touching the Raising and Lowering bolts or the bracket will break.
Never use power tools for this operation.

The method for adjusting the verticality of the DUT platform the sequence is as follows:

1) Unscrew the 6 bolts in the back by at least 3 turns, using a 13mm wrench manually.



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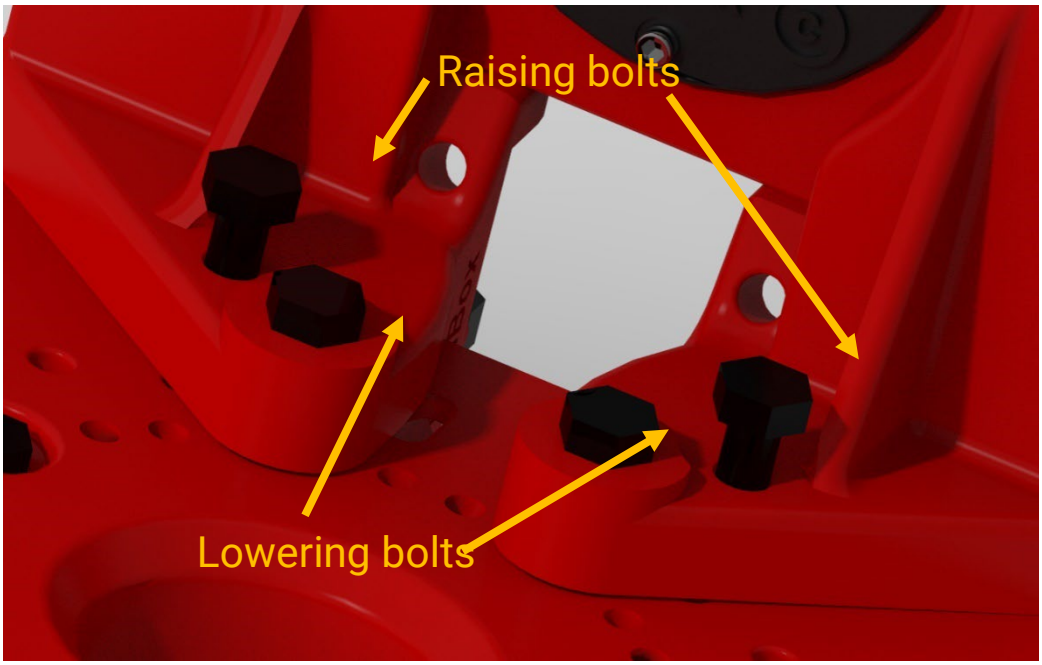
2) Unscrew the 2x lowering bolts by 5 turns, now the DUT platform is loosened.



3) Using the laser guide for reference to the horn post target. Gently push the platform forward to keep pressure on the raising bolts while adjusting the raising bolts up or down to get the alignment desired.
4) When the alignment is found, use the 2x lowering bolt to lock this position in place, DO NOT OVERTIGHT.
5) Then screw back the 6x Bolts in the back to hold the DUT platform in place, DO NOT OVERTIGHT.
6) Always check your vertical alignment during the procedure to make sure you don't lose your alignment. You may need several cycle of adjustment to get it right. Don't hesitate to contact us if you have issues with this process.

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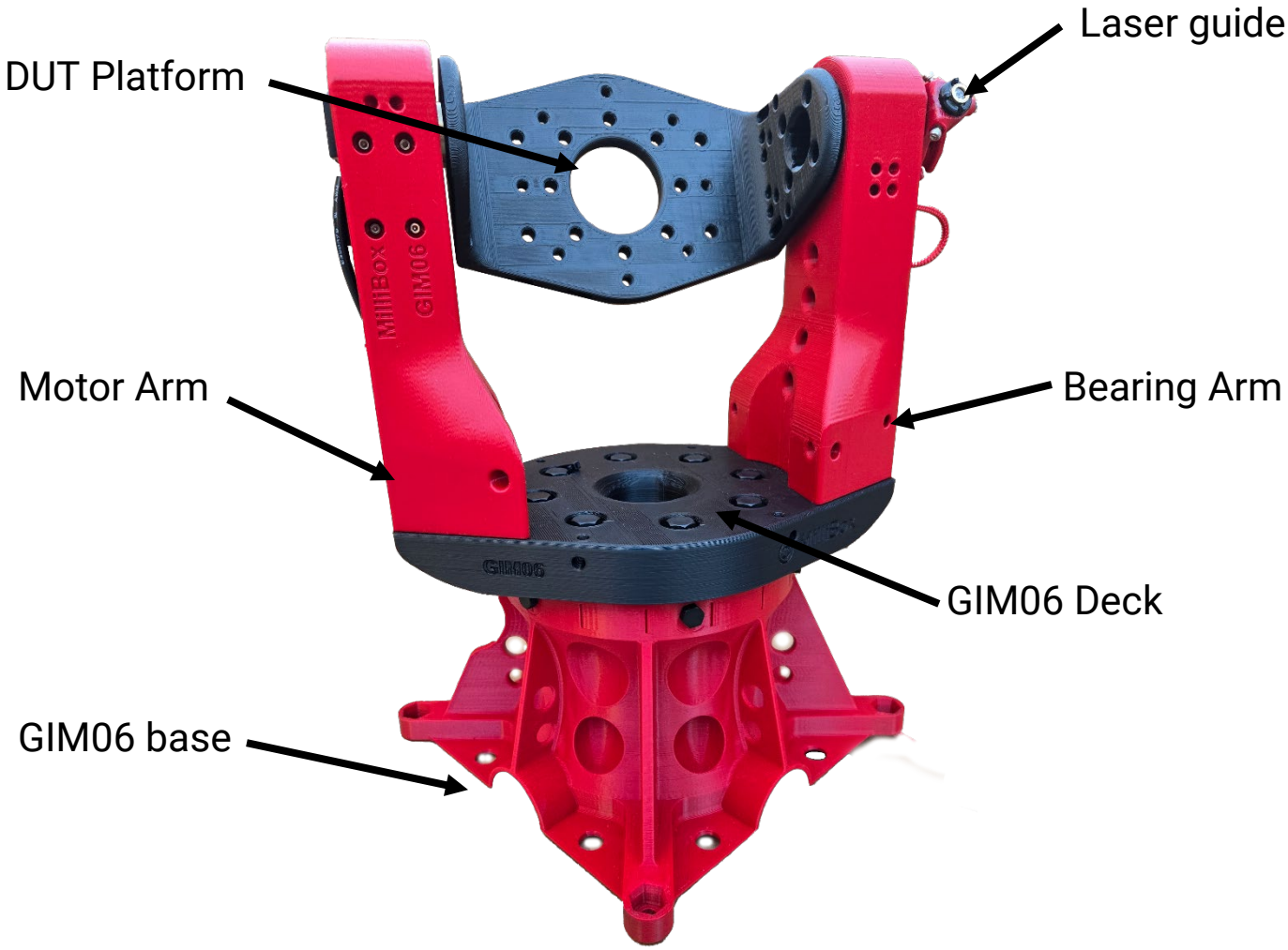
GIM06 positioner:

Getting to know the GIM06 positioner assembly:

GIM06 is a Horizontal Vertical positioner replacing GIM01



The DUT Platform is the piece where you can mount your DUT using one of the many bolt prepared for ISO M6 bolts provided. The DUT platform is recessed 50mm from the rotation axis, this provides some room to accommodate a DUT and its mounts
The GIM06 base is a common base that can be used for many other GIM0x positioners.
The GIM06 arms are asymmetrical such that the motor is on one side in direct drive mode (without gears) while the bearing, the laser and the cable passthrough are on the other side.arm. The laser guide is positioned on the exterior at 142mm from the rotation center.
GIM06 wiring is mainly run within the body of the positioner.

Base details:

Locate the different components constituting the GIM04 Base assembly.

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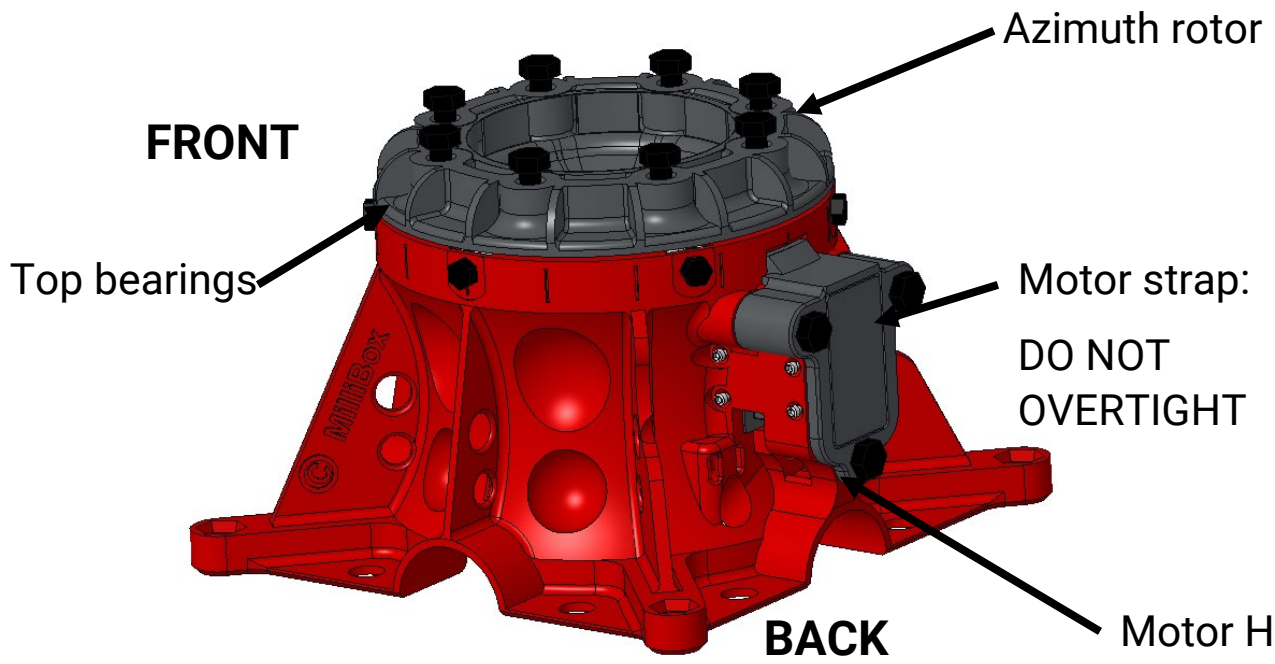

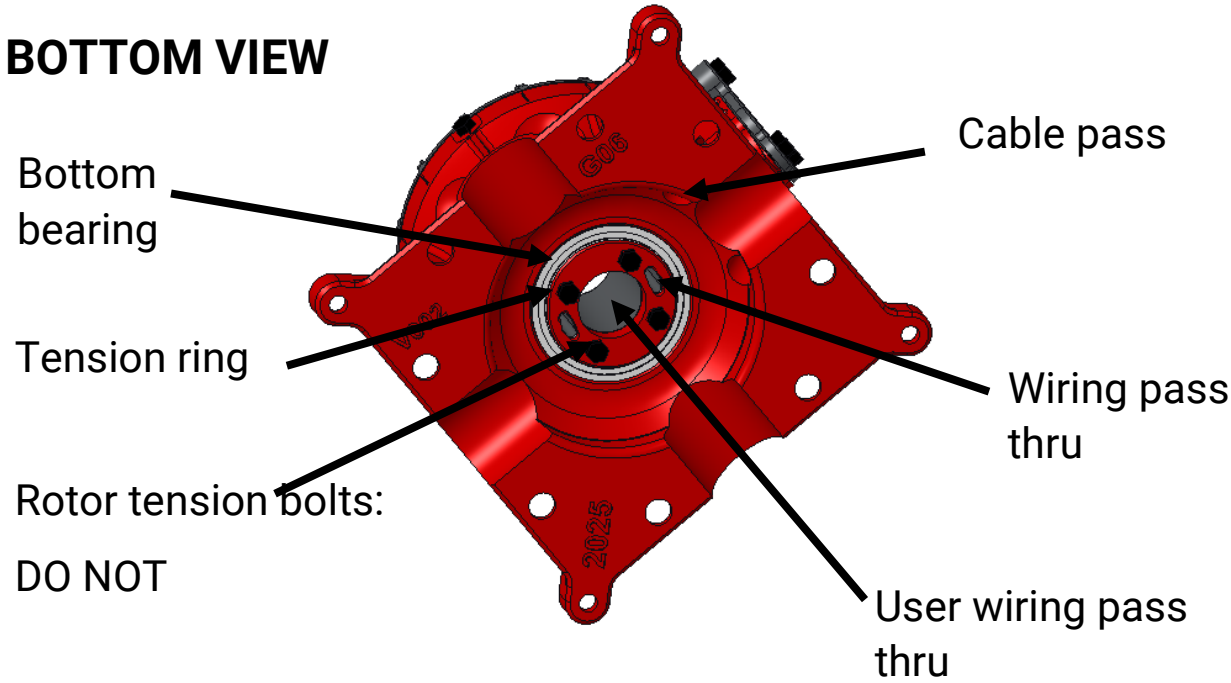

Hands details:

Locate the different components constituting the Hands assembly.

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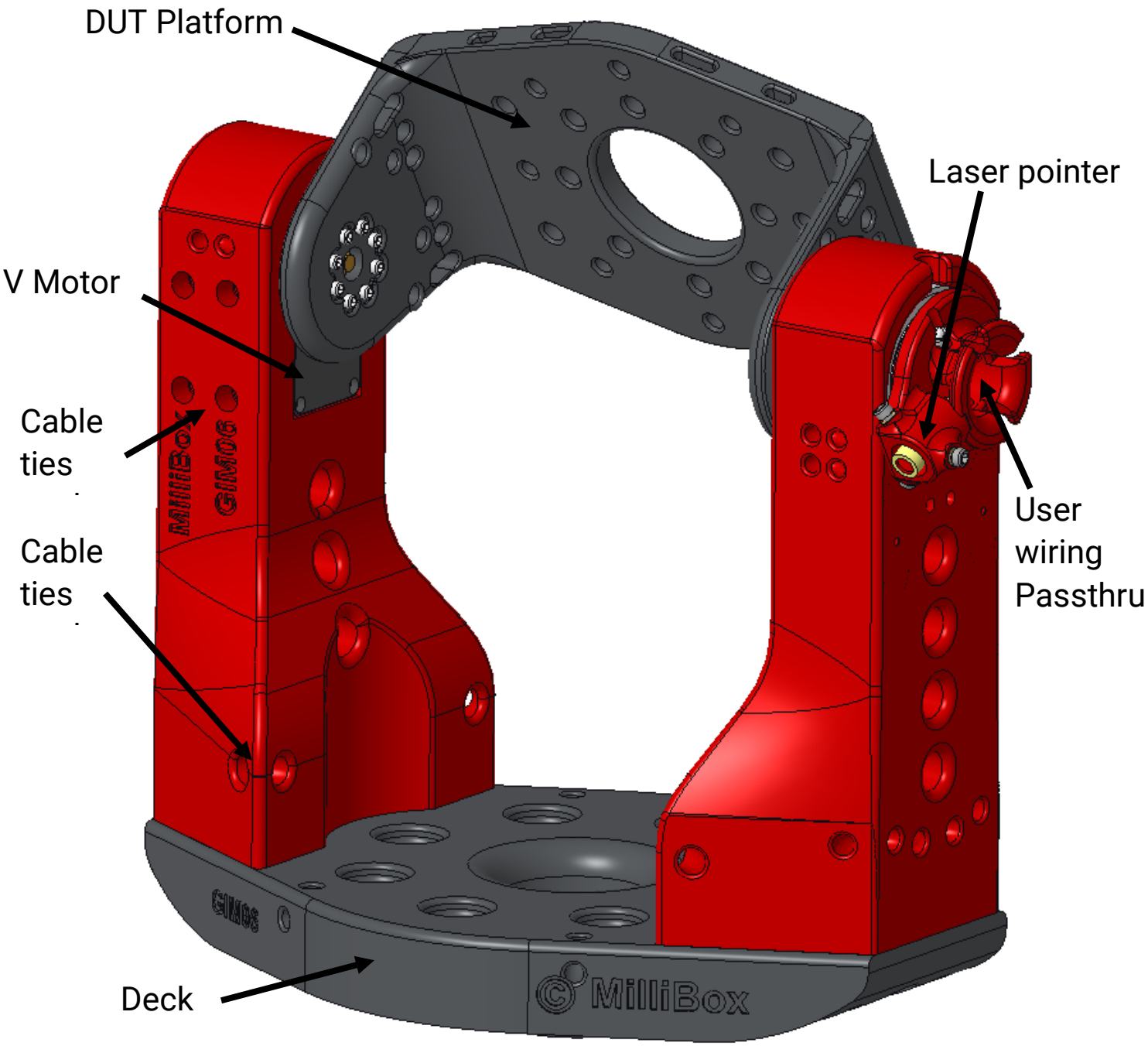

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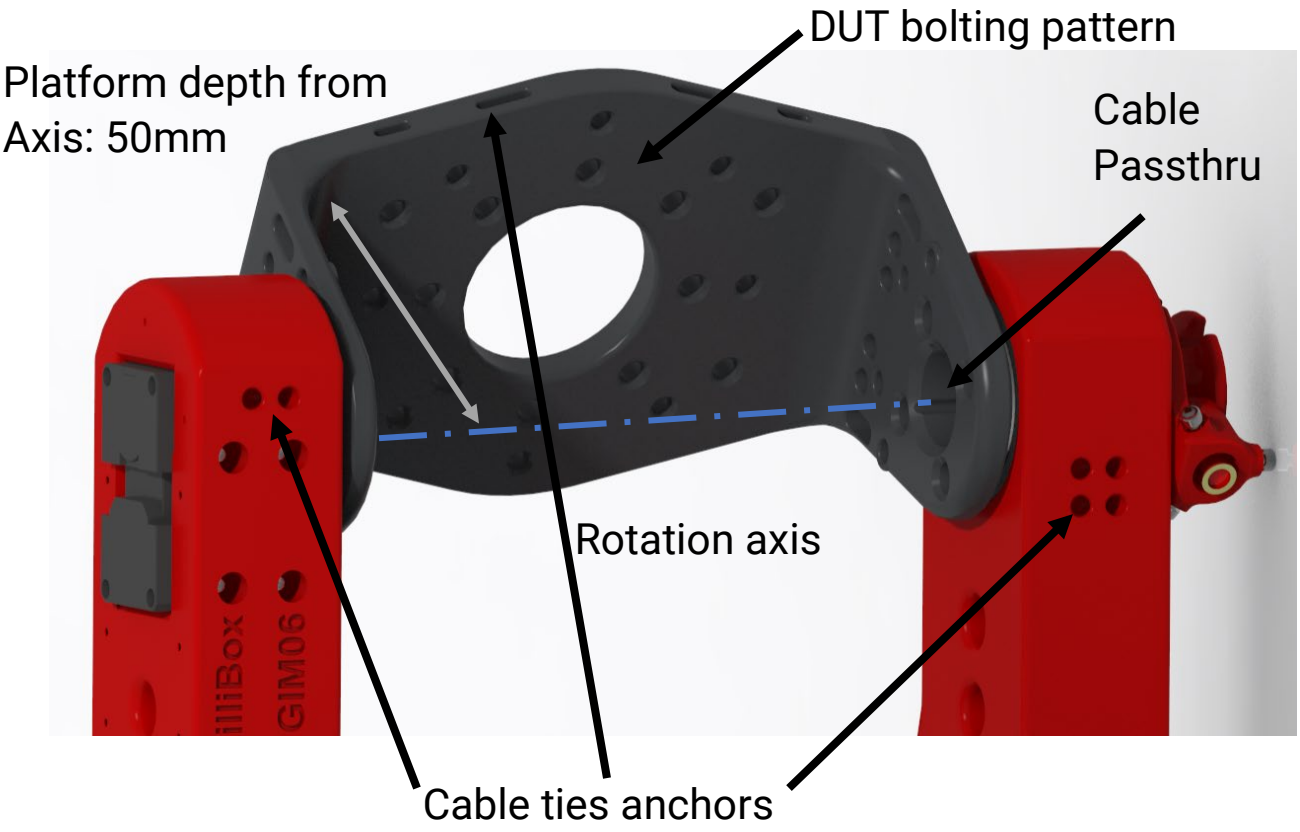
Platform details:

The platform is a solid piece attached directly to the motor on one side and held by bearings on the other side. A simple bolting pattern features all ISO M6 mounts, some tapped some through hole.



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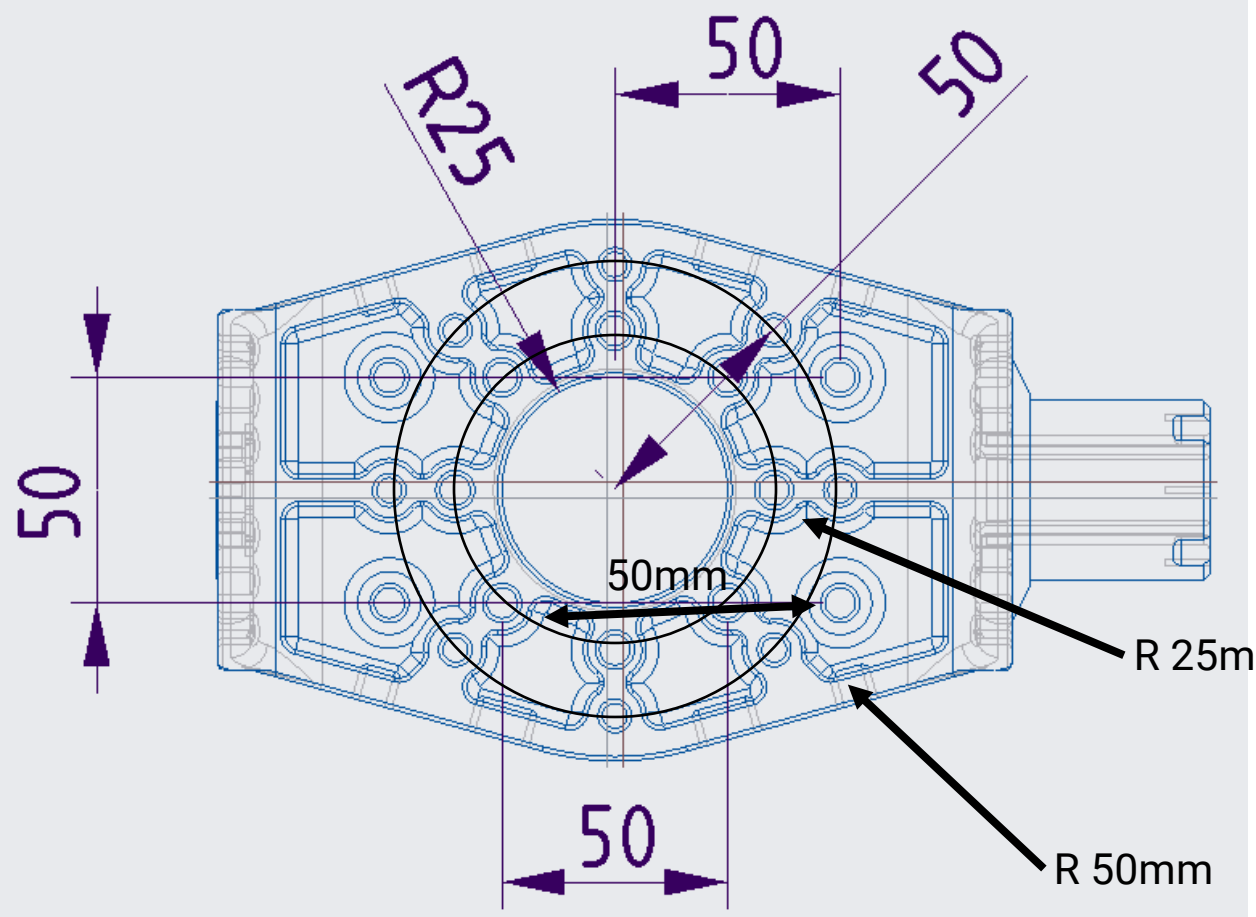
DUT Platform mounting dimensions:



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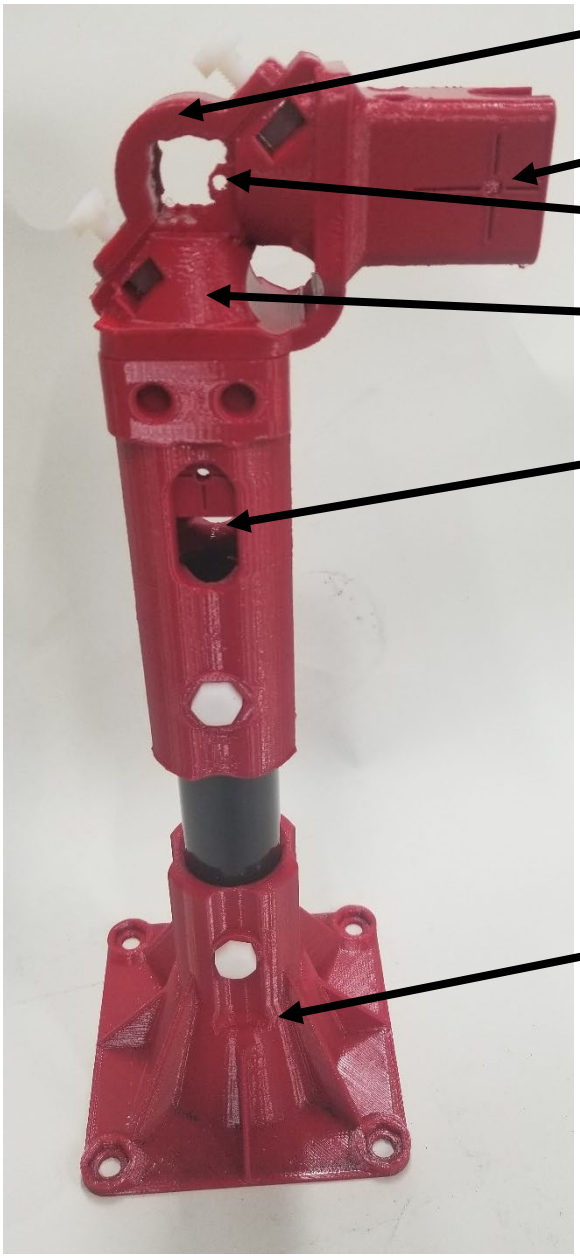
HOR0x Horn Post:

Getting to know the HOR0x Horn post assembly:



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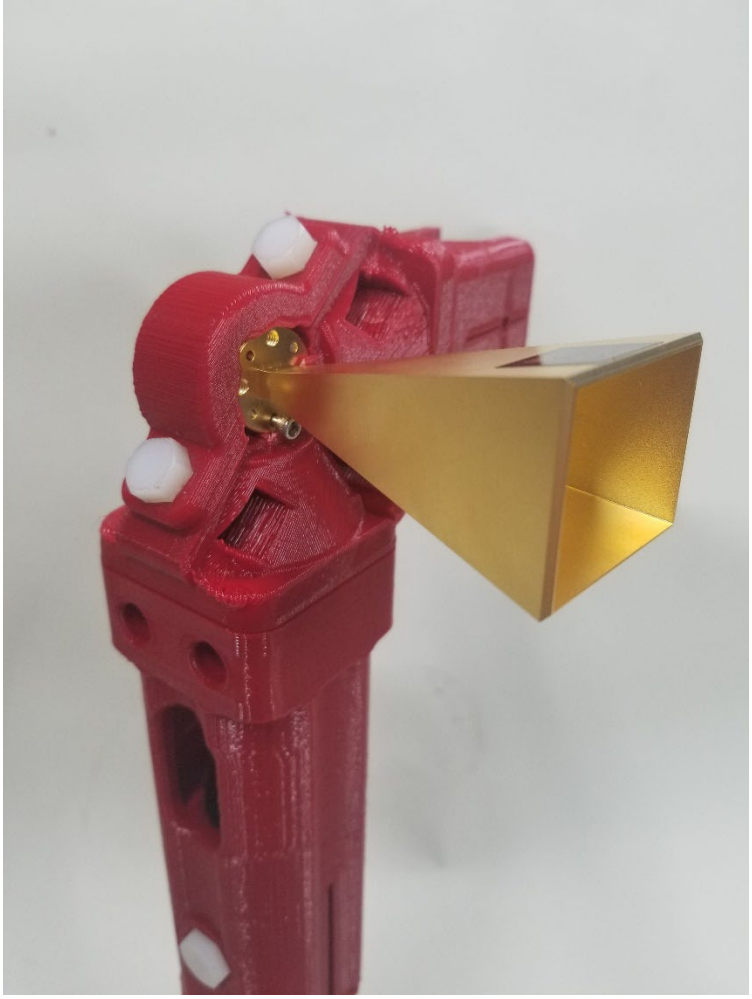
To mount a WR2.2 to WR15 horn, open the clamp locate the small alignment cues which are to be aligned with the horn captive bolts for proper polarization, remove the horn to coax adapter bolts and fit them through the alignment cues like shown below:



The horn holder base is press fitted in the post such that H, and V polarization position can be switched easily without disassembling the horn from the clamp.

The horn holder base is also used as the bull's eye target for the laser crosshair. It is usually easier to have the Laser target oriented toward the MBX chamber door for visibility.
A 90deg Coax adapter is preferred and positioned such that the coax cable goes away from the horn holder base and loops back into the post passthru and down through the lower deck of the chamber.

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Customization:

Horn holder customization

The default horn holder is designed to hold a standard WR 28 type flange. If your horn is not one of those or does not fit, you can contact Milliwave at millibox@milliwavess.com to get a quote for a custom horn holder designed for you.
We have alternate Horn Holder Clamp like WR2.2 to 15 WR34, WR19-22, WR28, Mixer holder, dual polarized horn holder etc… contact us for more details.
If you want a custom holder you will need to provide the mechanical drawing or stp file for your horn. If you do not have those, you can send your horn to Milliwave for the time the horn holder is designed.

DUT bracket design

The default platform offers a plethora of mounting options to install your DUT onto it. In most cases, you will need to design a bracket which will be the mechanical interface between your DUT and the platform. A 3D printed bracket is usually the most efficient way to do this. However, if you don't want to go through the effort of building your own bracket, Milliwave does offer this customization work as a service. You will need to provide the key mechanical features of your board (mounting hole position and dimension) and position of the center of your phase array in order to get a quote. In most cases you can get a custom bracket in less than a week.

MilliBox customization

MilliBox has a modular construction by design which invites mods and customization. Even though Milliwave can only guarantee its own design and cannot support parts that have been modified or re-designed, it does support various customization projects based on MilliBox architecture. Some want larger chambers, some want multiple 3D positioner units, some want clusters of chambers, some want temperature-controlled chambers, we can help you with those requirements. Contact millibox@milliwavess.com to start a custom project.

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Software Section:

Software installation

License information:

MilliBox® MBX software is under GPL 3.0 or later license.
Versions 23.1 and earlier were licensed under Apache 2.0 but this license has been revoked and replaced by the above license.
A copy of this license can be found in C:/SWMilliBox/MBX/COPYING
Copyrights are always preserved to their rightful owners:
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Python® and other Python modules required are:

- Python is owned by PSF with a license compatible with GPL
- Contourpy under 3-Clause BSD license
- Fonttools under MIT license
- Kiwisolver under 3-Clause BSD license
- Numpy under 3-Clause BSD license
- Matplotlib under PSF license compatible with BSD
- Pillow under HPND license compatible with GPL
- Pyserial under BSD license
- Python-dateutil under 3-Clause BSD license
- PyVISA under MIT license
- Pyvisa-py under MIT license
- Scipy under LGPL 2.1 or later license
- Six under MIT license

System requirements:

x86 PC with Win7 or later, Ubuntu 22.04.5 LTS or later, or OSX Mojave 10.14.3. This software can easily be ported to other operating systems.
2x USB2.0 ports, one for control data and one can be a charge port for the laser guide.
Python 2.7.x or later

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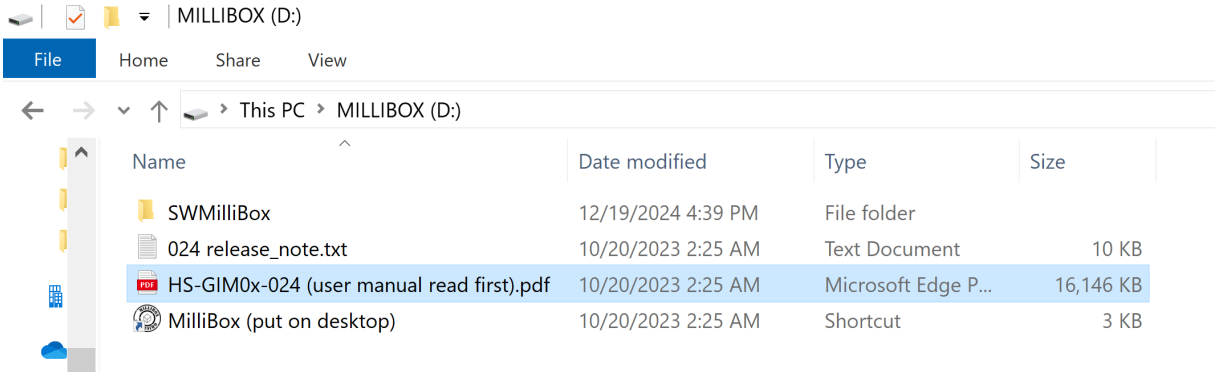
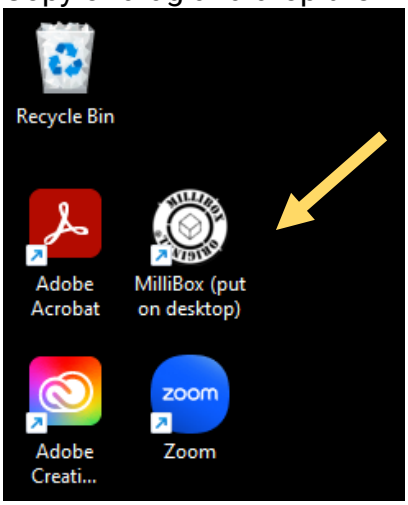
Install the release package:

Plug in the provided USB or unzip the downloaded MilliBox Software onto your machine. You should see the following components:



Copy SWMilliBox folder to C:\

Copy or drag and drop the MilliBox link logo to your desktop



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Setting up Python on Windows operating system

MilliBox SW controller is compatible with Python 2.7 and later and is tested up to Python 3.12 at the time of writing this manual.

Step 1:
First, you must check if python is already installed. It is easy to accidentally install multiple versions of python, especially on a shared computer. Use the start menu to open a command prompt window and enter `py --list`

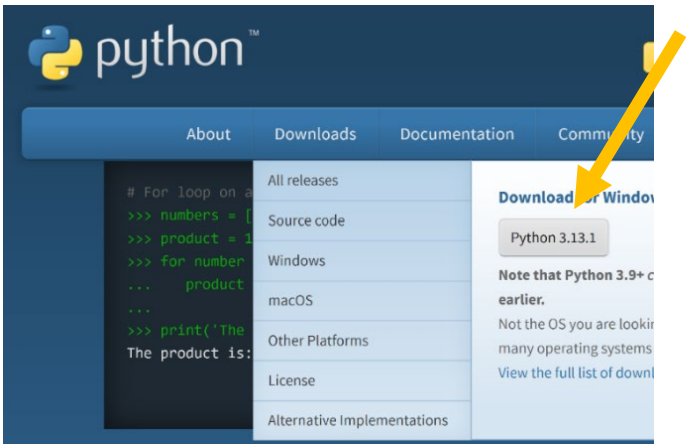
```
C:\Windows\System32>py --list
 -V:3.13 *        Python 3.13 (64-bit)
 -V:3.12          Python 3.12 (64-bit)
```

`py -3` will always run the version of Python 3 with the highest version number.

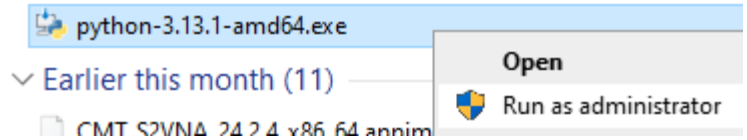
If the result is `'py' is not recognized as an internal or external command, operable program or batch file`, then the python launcher is not installed. Close the command prompt and go to Step 2.

If the result is a list of installed python versions, then a version of python and the python launcher are installed. If one of the installed versions starts with 3, you can go to Step 3, to install the python packages required to run the MilliBox software. Otherwise, go to Step 2 to install a more recent version of Python.

Step 2:
Open the website `python.org` in your browser of choice. Hover your mouse over the word Download and then click on the button that appears with the text "`Python 3.xx.xx`". This will download the installer for the latest release of Python.



Find the installer in your downloads folder. Right click it and select Run as Administrator.



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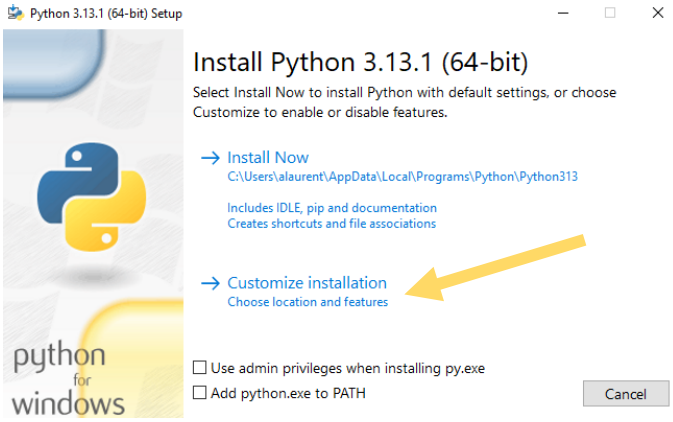
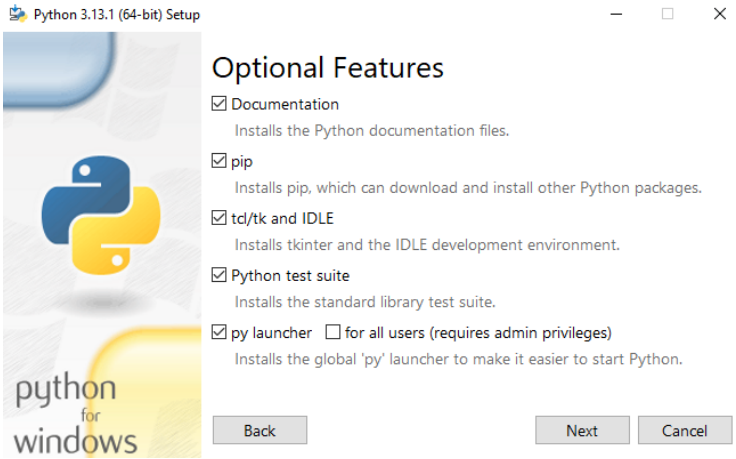
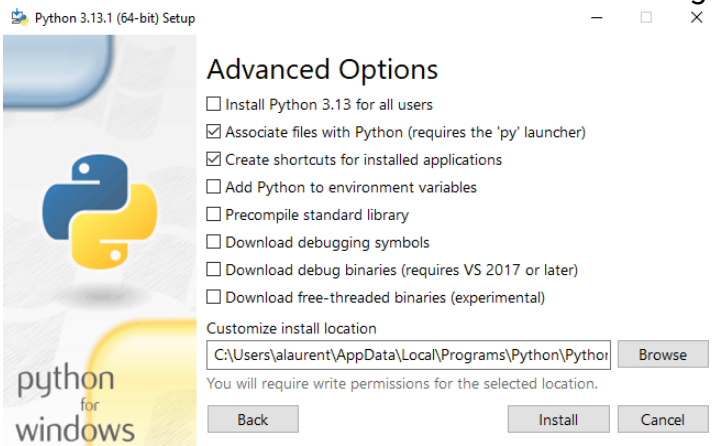
When the installer opens, leave both checkboxes unchecked, and select "`Customize Installation`".



Make sure the boxes are checked like in this image, then click next.



Make sure the boxes are checked like in this image, then click install.



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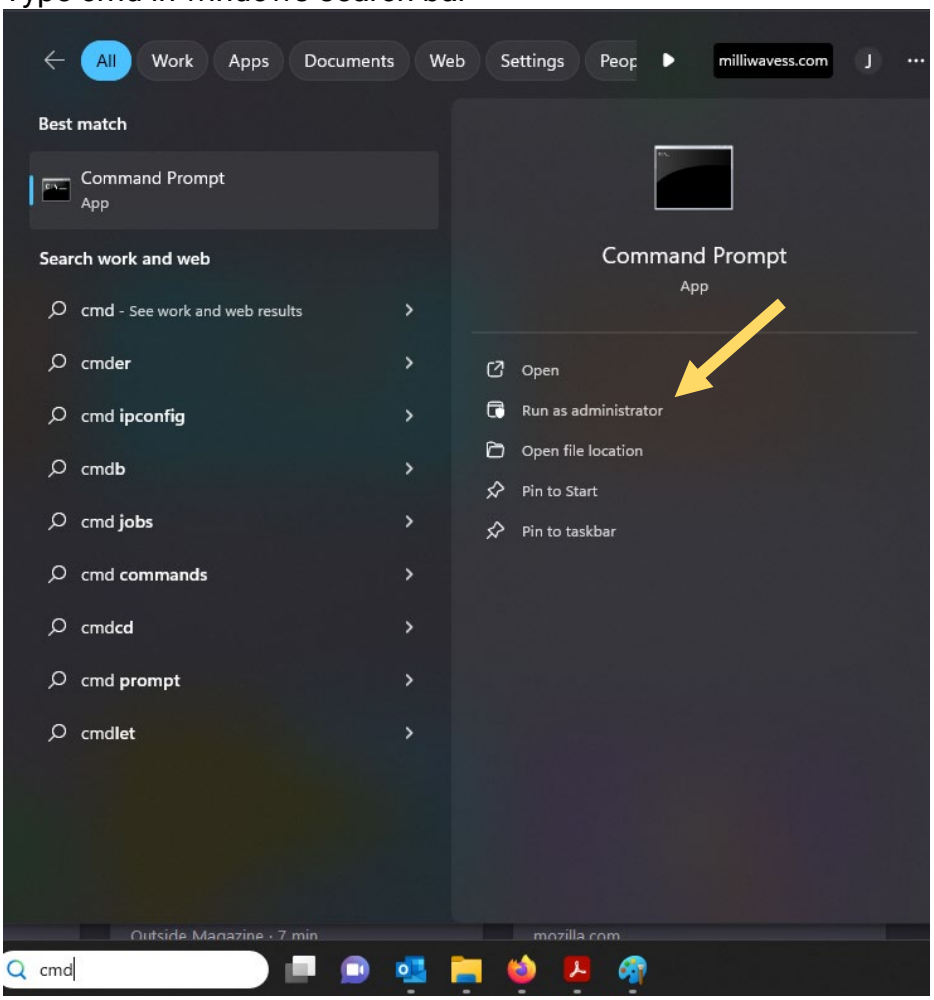
Step 3:
Type cmd in windows search bar



Here select “Run as administrator”.
In it type: `py -3 -m pip install pip --upgrade pip`

```
C:\Windows\system32>py -3 -m pip install --upgrade pip
Requirement already satisfied: pip in c:\users\alaurent\appdata\local\programs\python\python313\lib\site-packages (25.0)
```

This ensures that pip is updated to the latest version.

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Then we install matplotlib which has a lot of the graphical resources we need for our software:

Type: `py -3 -m pip install matplotlib` in the same command shell like so:

```
C:\Windows\system32>py -3 -m pip install matplotlib
Collecting matplotlib
  Downloading matplotlib-3.10.0-cp313-cp313-win_amd64.whl.metadata (11 kB)
Collecting contourpy>=1.0.1 (from matplotlib)
  Downloading contourpy-1.3.1-cp313-cp313-win_amd64.whl.metadata (5.4 kB)
Collecting cycler>=0.10 (from matplotlib)
  Downloading cycler-0.12.1-py3-none-any.whl.metadata (3.8 kB)
Collecting fonttools>=4.22.0 (from matplotlib)
  Downloading fonttools-4.55.6-cp313-cp313-win_amd64.whl.metadata (169 kB)
Collecting kiwisolver>=1.3.1 (from matplotlib)
  Downloading kiwisolver-1.4.8-cp313-cp313-win_amd64.whl.metadata (6.3 kB)
Collecting numpy>=1.23 (from matplotlib)
  Downloading numpy-2.2.2-cp313-cp313-win_amd64.whl.metadata (60 kB)
Collecting packaging>=20.0 (from matplotlib)
  Using cached packaging-24.2-py3-none-any.whl.metadata (3.2 kB)
Collecting pillow>=8 (from matplotlib)
  Downloading pillow-11.1.0-cp313-cp313-win_amd64.whl.metadata (9.3 kB)
Collecting pyparsing>=2.3.1 (from matplotlib)
  Downloading pyparsing-3.2.1-py3-none-any.whl.metadata (5.0 kB)
Collecting python-dateutil>=2.7 (from matplotlib)
  Downloading python_dateutil-2.9.0.post0-py2.py3-none-any.whl.metadata (8.4 kB)
Collecting six>=1.5 (from python-dateutil>=2.7->matplotlib)
  Downloading six-1.17.0-py2.py3-none-any.whl.metadata (1.7 kB)
Downloading matplotlib-3.10.0-cp313-cp313-win_amd64.whl (8.0 MB)
   ---------------------------------------- 8.0/8.0 MB 2.5 MB/s eta 0:00:00
Downloading contourpy-1.3.1-cp313-cp313-win_amd64.whl (220 kB)
Downloading cycler-0.12.1-py3-none-any.whl (8.3 kB)
Downloading fonttools-4.55.6-cp313-cp313-win_amd64.whl (2.2 MB)
   ---------------------------------------- 2.2/2.2 MB 2.5 MB/s eta 0:00:00
Downloading kiwisolver-1.4.8-cp313-cp313-win_amd64.whl (71 kB)
Downloading numpy-2.2.2-cp313-cp313-win_amd64.whl (12.6 MB)
   ---------------------------------------- 12.6/12.6 MB 1.7 MB/s eta 0:00:00
Using cached packaging-24.2-py3-none-any.whl (65 kB)
Downloading pillow-11.1.0-cp313-cp313-win_amd64.whl (2.6 MB)
   ---------------------------------------- 2.6/2.6 MB 1.4 MB/s eta 0:00:00
Downloading pyparsing-3.2.1-py3-none-any.whl (107 kB)
Downloading python_dateutil-2.9.0.post0-py2.py3-none-any.whl (229 kB)
Downloading six-1.17.0-py2.py3-none-any.whl (11 kB)
Installing collected packages: six, pyparsing, pillow, packaging, numpy, kiwisolver, fonttools, cycler, python-dateutil, contourpy, matplotlib
  WARNING: The scripts f2py.exe and numpy-config.exe are installed in 'C:\Users\alaurent\AppData\Local\Programs\Python\Python313\Scripts' which is not on PATH.
  Consider adding this directory to PATH or, if you prefer to suppress this warning, use --no-warn-script-location.
  WARNING: The scripts fonttools.exe, pyftmerge.exe, pyftsubset.exe and ttx.exe are installed in 'C:\Users\alaurent\AppData\Local\Programs\Python\Python313\Scripts' whi
ch is not on PATH.
  Consider adding this directory to PATH or, if you prefer to suppress this warning, use --no-warn-script-location.
```

Pip will install matplotlib but also all other modules that are dependencies for matplotlib, when the installation is complete this is what we see in the picture above. Everything is as expected.

Now we need to install modules that are required to communicate and automate instruments through the VISA interface:

Install pyVISA by typing: `py -3 -m pip install pyvisa`

```
C:\Windows\System32>py -3 -m pip install pyvisa
Collecting pyvisa
  Using cached PyVISA-1.14.1-py3-none-any.whl.metadata (7.1 kB)
Requirement already satisfied: typing-extensions in c:\users\alaurent\appdata\local\programs\python\python313\lib\site-packages (from pyvisa) (4.12.2)
Using cached PyVISA-1.14.1-py3-none-any.whl (176 kB)
Installing collected packages: pyvisa
  WARNING: The scripts pyvisa-info.exe and pyvisa-shell.exe are installed in 'C:\Users\alaurent\AppData\Local\Programs\Python\Python313\Scripts' which
  Consider adding this directory to PATH or, if you prefer to suppress this warning, use --no-warn-script-location.
Successfully installed pyvisa-1.14.1
```

Install pyVISA-py by typing: `py -3 -m pip install pyvisa-py`

```
C:\Windows\system32>py -3 -m pip install pyvisa-py
Collecting pyvisa-py
  Downloading PyVISA_py-0.7.2-py3-none-any.whl.metadata (6.6 kB)
Collecting pyvisa>=1.13.0 (from pyvisa-py)
  Downloading PyVISA-1.14.1-py3-none-any.whl.metadata (7.1 kB)
Collecting typing-extensions (from pyvisa-py)
  Downloading typing_extensions-4.12.2-py3-none-any.whl.metadata (3.0 kB)
Downloading PyVISA_py-0.7.2-py3-none-any.whl (75 kB)
Downloading PyVISA-1.14.1-py3-none-any.whl (176 kB)
Downloading typing_extensions-4.12.2-py3-none-any.whl (37 kB)
Installing collected packages: typing-extensions, pyvisa, pyvisa-py
  WARNING: The scripts pyvisa-info.exe and pyvisa-shell.exe are installed in '
  Consider adding this directory to PATH or, if you prefer to suppress this wa
Successfully installed pyvisa-1.14.1 pyvisa-py-0.7.2 typing-extensions-4.12.2
```


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Then install Scipy scientific module by typing: `py -3 -m pip install scipy`

```
C:\Windows\system32>py -3 -m pip install scipy
Collecting scipy
  Downloading scipy-1.15.1-cp313-cp313-win_amd64.whl.metadata (60 kB)
Requirement already satisfied: numpy<2.5,>=1.23.5 in c:\users\alaurent\appdata\local\programs\python\python313\lib\site-packages (from scipy) (2.2.2)
Downloading scipy-1.15.1-cp313-cp313-win_amd64.whl (43.6 MB)
   ---------------------------------------- 43.6/43.6 MB 1.9 MB/s eta 0:00:00
Installing collected packages: scipy
Successfully installed scipy-1.15.1
```

Then install pyserial by typing: `py -3 -m pip install pyserial`

```
C:\Windows\system32>py -3 -m pip install pyserial
Collecting pyserial
  Using cached pyserial-3.5-py2.py3-none-any.whl.metadata (1.6 kB)
Using cached pyserial-3.5-py2.py3-none-any.whl (90 kB)
Installing collected packages: pyserial
  WARNING: The scripts pyserial-miniterm.exe and pyserial-ports.exe
 PATH.
  Consider adding this directory to PATH or, if you prefer to suppre
Successfully installed pyserial-3.5
```

At the end of the installation, you can check that all required python modules are installed by typing the command: `py -3 -m pip list`

```
C:\Windows\system32>py -3 -m pip list
Package           Version
----------------- -----------
contourpy         1.3.1
cycler            0.12.1
fonttools         4.55.6
kiwisolver        1.4.8
matplotlib        3.10.0
numpy             2.2.2
packaging         24.2
pillow            11.1.0
pip               25.0
pyparsing         3.2.1
pyserial          3.5
python-dateutil   2.9.0.post0
PyVISA            1.14.1
PyVISA-py         0.7.2
scipy             1.15.1
six               1.17.0
typing_extensions 4.12.2
```


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MBX code

From the path `C:\SWMilliBox\MBX\python\`, you can find all the files constituting the MilliBox software code base:

- dynamixel_functions.py
- dynamixel_sdk\
- mbx.py
- mbx_functions.py
- mbx_instrument.py
- mbx_plot.py
- mbx_postprocess.py
- mbx_realtimeplot.py
- mbx_scpi_connection.py
- mbx_test_config.py
- mbx_test_instrument.py
- mbx_visa_shell.py
- surf2stl.py

The configuration file stored and saved in this directory is:

- mbx.cfg

The role of each file is described in a later section of this document.

From Version 024 onward dynamixel_functions.py is no longer used for the serial port OS dependent drivers (.dll…). Instead the new dynamixel_sdk directory features a Python native driver based on Python module pySerial. As a result, dynamixel_functions.py will be removed from version 025 onward, and pySerial module needs to be installed when using MilliBox controller version 024 and later.

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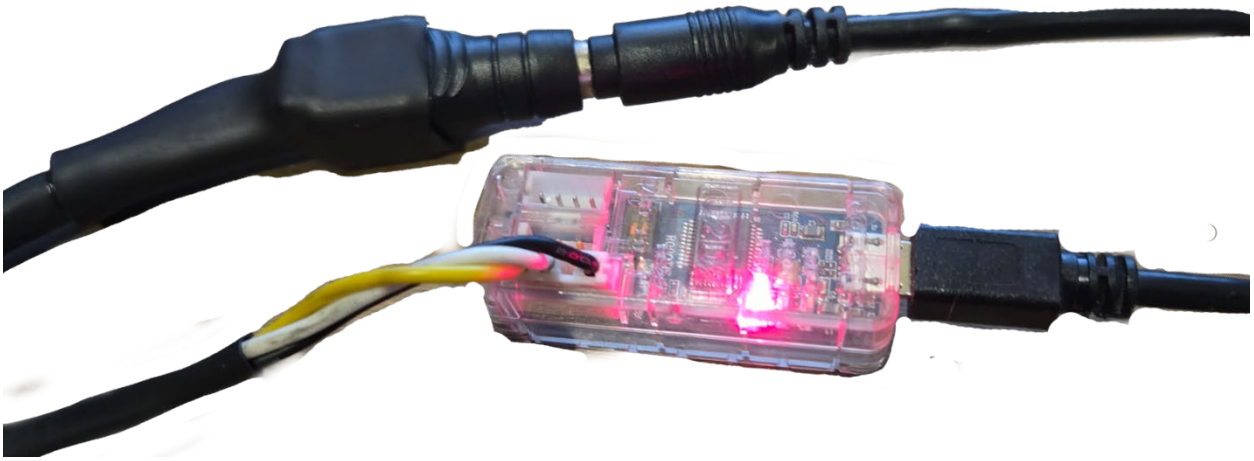
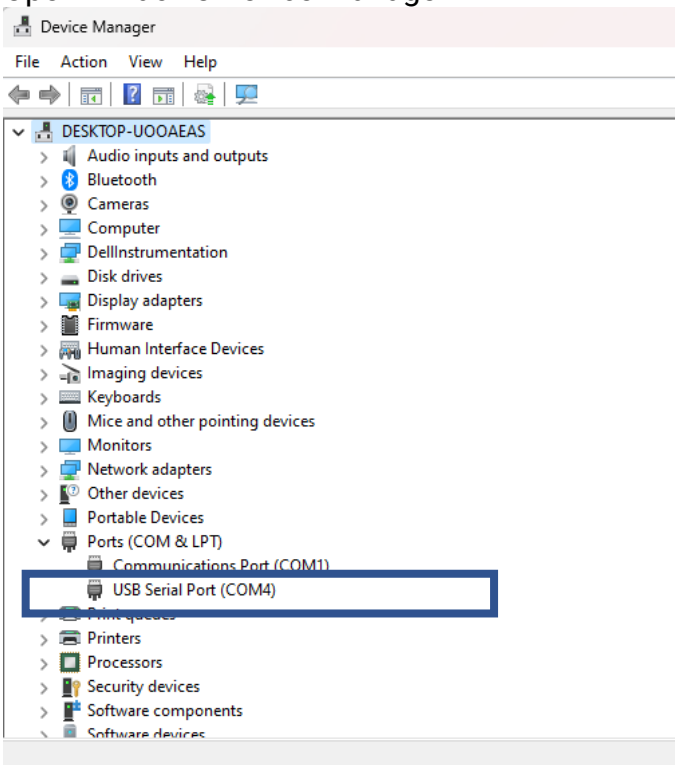
Finish configuration and testing the installation

Connect the USB dongle (U2D2) to the PC where the software installation was made.
Connect the positioner's power adapter to an AC outlet.



Open windows Device Manager:



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Windows assigns the COM port number automatically and it can be something other than 4. If you have multiple COM ports showing up and you are not sure which one is attached to GIM0x, just un-plug and plug the USB cable from your machine, and you should see which COM port is assigned to your GIM0x.

If you do not get a USB Serial Port (COMx) assigned by Windows, you can install the drivers manually as described in the troubleshooting section below.

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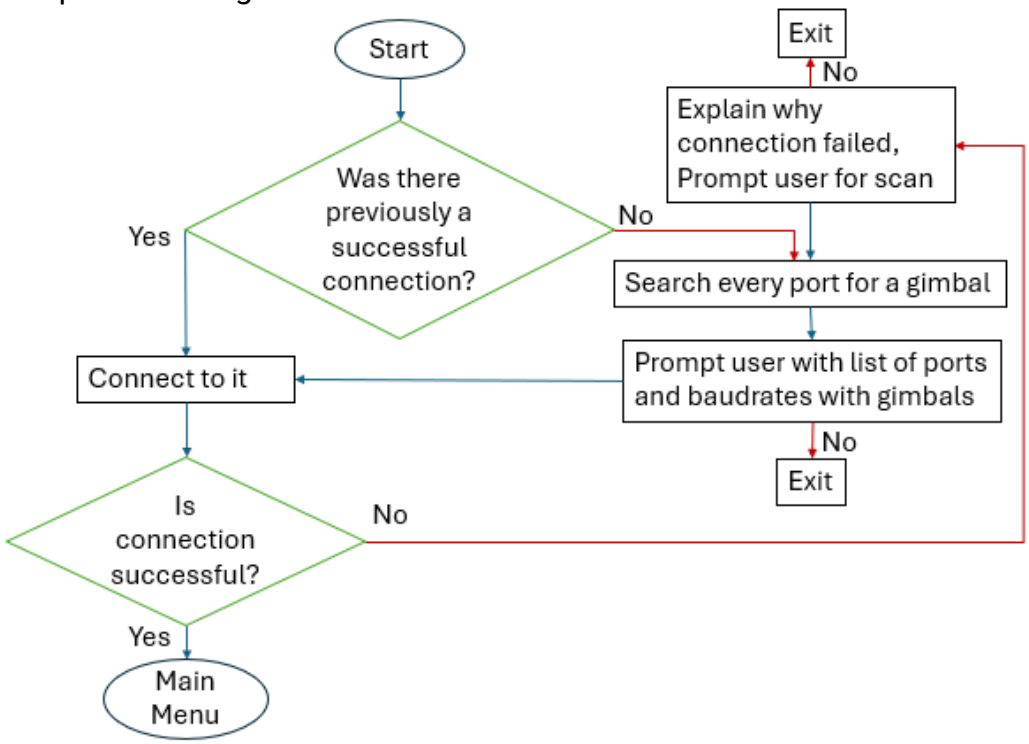
Now we can test the software.
Navigate to C:\SWMilliBox\MBX\python\
Or use the desktop MilliBox shortcut included in the release folder which does the same thing.
Then type the command `'py -3 mbx.py'`
When `mbx.py` starts for the first time it does three actions:

- First it scans all COM ports to identify which one is connected to an MBX Gimbal, connects to a gimbal if one is found, then saves that value to `mbx.cfg`.
- Second it runs the diagnostic and auto identification of the positioner type, checks all motor settings are correct and retrieves the configuration stored in `mbx.cfg`.
- Third it displays the MAIN MENU

C:\SWMilliBox\MBX\python> py -3 mbx.py

The port scanning behavior works like this:



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Scanning all ports looks like this:

```
MilliBox Software Release: 24.1
Python Version: 3.13.1 (tags/v3.13.1:0671451, Dec  3 2024,
19:06:28) [MSC v.1942 64 bit (AMD64)]

**** Found no previous connection to a gimbal. Running autoscan.
****


Checking all comports...


Port COM3 is not a FT232H (U2D2)

Port COM6 is a FT232H (U2D2)
Checking all supported baudrates...

Scanning at baudrate 1000000 bps
Succeeded to open the port (COM6)!
Succeeded to set the baudrate to 1000000!
PH42_020 identified at ID 1
XH540_V270 identified at ID 2
XH540_V270 identified at ID 3
==> Port COM6 is a GIM on baudrate 1000000

Scanning at baudrate 57600 bps
Succeeded to open the port (COM6)!
Succeeded to set the baudrate to 57600!
==> Port COM6 is not a GIM on baudrate 57600, error 25

Done scanning all comports...

**** CHOOSING PORT COM6 AT BAUDRATE 1000000 ****

Connecting to COM6 at baudrate 1000000
```


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Diagnostic and configuration section looks like this, note that it varies with positioner type:

```
device = COM6   port = COM6
Succeeded to open the port (COM6)!
Succeeded to set the baudrate!
===== Gimbal type CHECK =====
====> Motor4 (P) motor identified
====> GIM04x identified
====> PH42 Base identified
===== motor configuration CHECK =====
torque for motor 1 is already disabled
torque for motor 2 is already disabled
torque for motor 3 is already disabled
torque for motor 4 is already disabled
flash access set
operating mode H = 4
**** Operating mode is OK ****
operating mode V = 4
**** Operating mode is OK ****
operating mode R = 4
**** Operating mode is OK ****
drive mode R = 3
reverse motor drive mode is OK
operating mode P = 4
**** Operating mode is OK ****
H moving threshold OK
V moving threshold OK
P moving threshold OK
=== setting motors dynamic parameters ===
torque now enabled for motor 1
torque now enabled for motor 2
torque now enabled for motor 3
torque now enabled for motor 4
ram access enabled
H PID configuration set
V PID configuration set
P PID configuration set
verifying all settings
H position D gain : 0 = 0
H position P gain : 3000 = 3000
H position I gain : 3000 = 3000
H FF1 gain : 0 = 0
V position D gain : 0 = 0
```


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```
V position P gain : 1000 = 1000
V position I gain : 3000 = 3000
V FF1 gain : 0 = 0
P position D gain : 0 = 0
P position P gain : 1000 = 1000
P position I gain : 3000 = 3000
P FF1 gain : 0 = 0
BOOT UP MOTOR POSITION CHECK before re-alignement
Current position for motor 1  is =  -0.060444444444444446
degree, Position is : -204 steps,  Offset is : 187
Current position for motor 2  is =  95.361328125 degree,
Position is : 3133 steps,  Offset is : 3015
Current position for motor 4  is =  0.0 degree, Position is :
2048 steps,  Offset is : -845
************************************************************
motor=1   led=0   offset=   187   goalpos=  -204   drmode=0
motor=2   led=0   offset=  3015   goalpos=  3133   drmode=0
motor=4   led=0   offset=  -845   goalpos=  2048   drmode=0
************************************************************
firmware version of motor H is OKAY
motor=1   led=0   offset=   187   goalpos=  -204   drmode=0
power cycle detected --> re-alignment check needed
-> no compensation needed for motor 1
-> motor=1 LED set to 1
firmware version of motor V is OKAY
motor=2   led=0   offset=  3015   goalpos=  3133   drmode=0
power cycle detected --> re-alignment check needed
-> no compensation needed for motor 2
-> motor=2 LED set to 1
firmware version of motor P is OKAY
motor=4   led=0   offset=  -845   goalpos=  2048   drmode=0
power cycle detected --> re-alignment check needed
-> no compensation needed for motor 4
-> motor=4 LED set to 1
************************************************************
motor=1   led=1   offset=   187   goalpos=  -204   drmode=0
motor=2   led=1   offset=  3015   goalpos=  3133   drmode=0
motor=4   led=1   offset=  -845   goalpos=  2048   drmode=0
************************************************************
*** set_motor_motion_default ***
H model is = 2000
V model is = 1140
P model is = 1150
****** GIM motion settings ******
    gim_type = 1
  num_motors = 4
```


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```
    accuracy = HIGH
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500,
'anglelim': [-180, 180]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10,
'anglelim': [-180, 180]}
           4 = {'model': 1150, 'vel': 97.61125, 'accel': 20,
'anglelim': [-180, 180]}
Device connected
GIM TYPE = HV
Found 4 motor(s)
going to zero position
+++++++++++++++ MilliBox Gimbal is ready  +++++++++++++++

H model is = 2000
V model is = 1140
P model is = 1150
GIM motion parameter not defined! Using default values
****** GIM motion settings ******
    gim_type = 1
  num_motors = 4
    accuracy = HIGH
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500,
'anglelim': [-180, 180]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10,
'anglelim': [-180, 180]}
           4 = {'model': 1150, 'vel': 97.61125, 'accel': 20,
'anglelim': [-180, 180]}
mbx.cfg saved to file
```

This completes the software initialization diagnostic and configuration, after this the menu can show.

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The MAIN MENU section looks like this:

```
******* Measurement Mode = NONE *******

*************************************************
*
*       Mode: NONE
* Instrument: ['SIMULATION']
*  Corr File: ---
*  Save Corr: ---
*     Zigzag: True
*   Position: (0.00, 0.09, 0.00)
*
************* MAIN MENU *************************
************ USE KEYBOARD ************************
* Press <ESC> or <q> to close ports and quit!
__________ MOVEMENT/ALIGNMENT __________
* use <arrow keys> or <ijkl> to adjust H and V angles
* use <[> or <]> to adjust polarization angle
* use <a> to reduce step size for finer alignment resolution
* use <s> to increase step size for coarser alignment resolution
* press <ZERO> key to store H0 V0 P0 position
* press <h> to go home to last saved H0 V0 P0 home position
* press <m> to open the direct move travel menu
* press <b> to start electronic beam alignment
* press <.> to print current position
_________ GIM MOTION SETTINGS __________
* press <g> to display GIM motion parameters
* press <v> to open the velocity setting menu
* press <r> to open the accel limit setting menu
* press <t> to open the angle limit setting menu
* press <e> to toggle accuracy setting
* press <w> to reset GIM parameters to default
__________ MEASUREMENT SETUP ___________
* press <y> to set measurement mode (VNA/SG+SA/SA/NONE) and set
equipment VISA address
* press <x> to get current power measurement
* press <n> to save current power measurement to file
* press <o> to display correction factor menu
* press <f> to force instrument re-initialization
__________ MEASUREMENT SWEEPS __________
* press <d> to start default plot H -90 90 V -90 90 Step 15deg
* press <c> to start accuracy position check menu
* press <z> to toggle zigzag movement mode for 2D sweeps
* press <1> to start a 1-D sweep
```


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```
* press <2> to start a 2-D sweep
* press <3> to start a 1-D sweep in E-plane and H-plane
_________ DATA POST-PROCESSING _________
* press <p> to plot from previous measurement
* press </> to display post-processing menu
___________ SPECIAL SETTINGS ___________
* press <:> to change motor baudrate configuration
* press <+> to reset offset for home position
* press <\> to toggle test menu
*********************************************************
```

The second time you run mbx.py, you will see this:

```
C:\SWMilliBox\MBX\python>py -3 mbx.py

MilliBox Software Release: 24.0
Python Version: 3.13.1 (tags/v3.13.1:0671451, Dec  3 2024, 19:06:28) [MSC v.1942 64 bit (AMD64)]

**** Previously connected to COM6 at baudrate 1000000. Attempting to re-connect... ****

Connecting to COM6 at baudrate 1000000
```

This indicates that the port and baudrate was saved to mbx.cfg. It will try to connect to that port and baudrate before performing an autoscan.

If instead you see:

```
C:\SWMilliBox\MBX\python>py -3 mbx.py

MilliBox Software Release: 24.0
Python Version: 3.13.1 (tags/v3.13.1:0671451, Dec  3 2024, 19:06:28) [MSC v.1942 64 bit (AMD64)]

**** Found no previous connection to a gimbal. Running autoscan. ****


Checking all comports...


Port COM3 is not a FT232H (U2D2)

Done scanning all comports...
Failed to find gimbal
U2D2 may not be plugged into computer
Press any key to terminate...
```

The COM port has not been created. Either the device is not plugged in to the computer or there is a connection error between the U2D2 and the computer. Identify the problem and address it until you see the top menu in the console.

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If instead you see:

```
C:\SWMilliBox\MBX\python>py -3 mbx.py

MilliBox Software Release: 24.0
Python Version: 3.13.1 (tags/v3.13.1:0671451, Dec  3 2024, 19:06:28) [MSC v.1942 64 bit (AMD64)]

**** Found no previous connection to a gimbal. Running autoscan. ****


Checking all comports...


Port COM3 is not a FT232H (U2D2)

Port COM6 is a FT232H (U2D2)
Checking all supported baudrates...

Scanning at baudrate 1000000 bps
Succeeded to open the port (COM6)!
Succeeded to set the baudrate to 1000000!
==> Port COM6 is not a GIM on baudrate 1000000, error 25

Scanning at baudrate 57600 bps
Succeeded to open the port (COM6)!
Succeeded to set the baudrate to 57600!
==> Port COM6 is not a GIM on baudrate 57600, error 25

Done scanning all comports...
Failed to find gimbal
COM6 at baudrate 1000000: Motors not found, motors may be unpowered or unplugged
COM6 at baudrate 57600: Motors not found, motors may be unpowered or unplugged
Press any key to terminate...
```

The COM port has been created and the U2D2 is communicating, but there is no motor responding to the U2D2. Either the motors are not receiving power or there is a connection error between the motors and the U2D2. Identify the problem and address it until you see the top menu in the console.

When you have the top menu and everything is ready, you can immediately test your setup by pressing key ‘d’ on the keyboard. The ‘d’ key runs a default 3D sweep and exercises most movement functions of the positioner.
The following warning will appear to call you to check everything once more, especially that nothing is in the way of the motion of the 3D positioner.

```
d
going to zero position
## Please make sure everything is ready to start measurement ##
#####      Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
```

When you are sure nothing is going to block the 3D positioner motion, hit the space bar on the keyboard, the default trial plot should start immediately.

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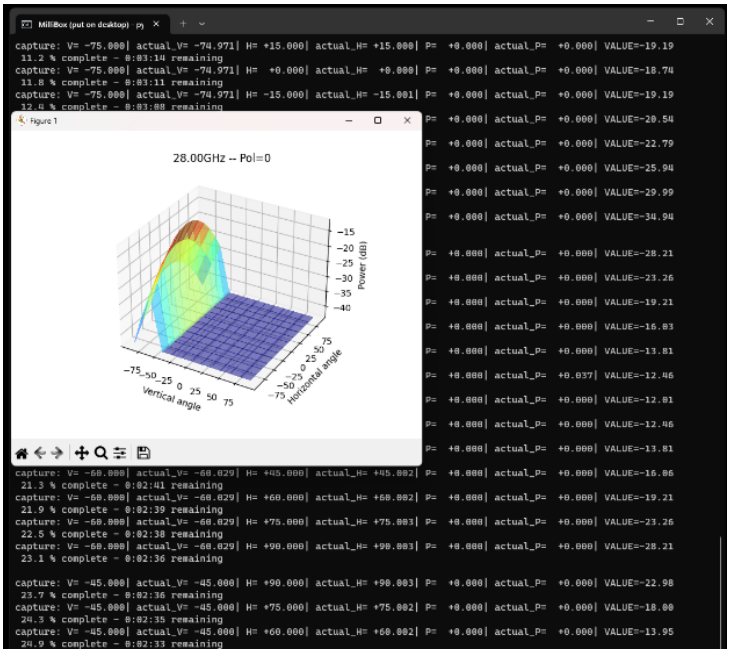
```
Plot data is saved in file : ..\..\MilliBox_plot_data\mbx_capture_2023-10-09-161240_2d_default.csv

**** Plotting frequency = 28.000GHz ****

 V range is = [-90. -75. -60. -45. -30. -15.   0.  15.  30.  45.  60.  75.  90.]
 H range is = [-90. -75. -60. -45. -30. -15.   0.  15.  30.  45.  60.  75.  90.]
capture: V= -90.000| actual_V= -90.000| H= -90.000| actual_H= -90.003| P=  +0.000| actual_P=  +0.000| VALUE=-43.20
  0.6 % complete - 0:12:03 remaining
```

The default plot is:

- -90 to +90 degree in Horizontal plane
- -90 to +90 degree in Vertical plane
- Step size 15 degree

It lasts about 10 minutes.
When using a HV positioner (GIM01, GIM03, GIM04) the screen should look like this:



At this point the 3D positioner setup is complete, and everything is working as designed.

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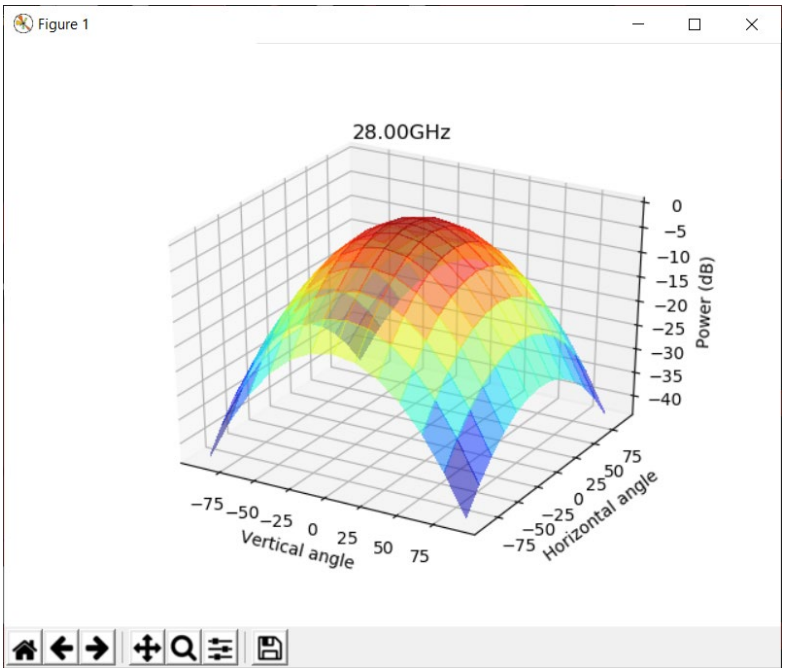
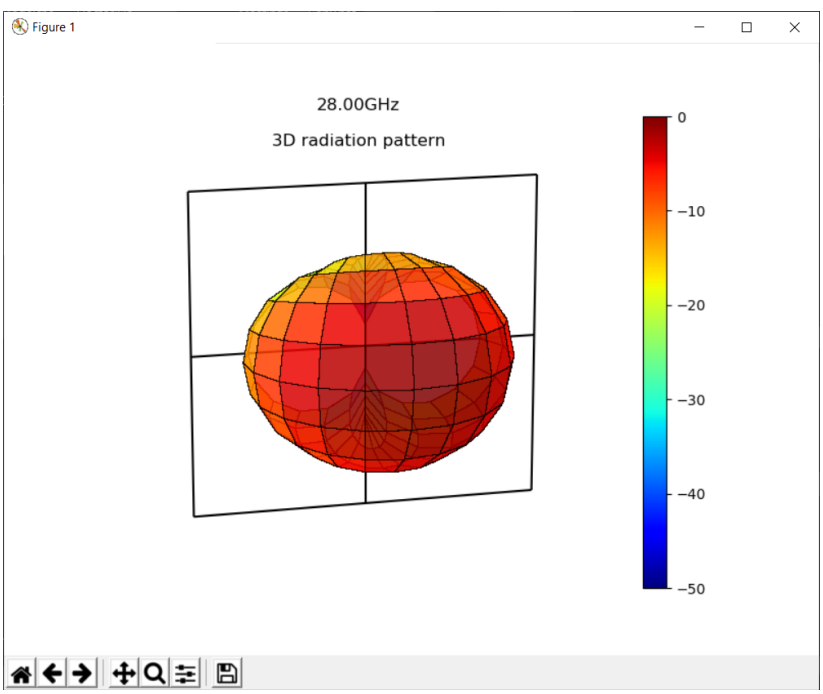
When the default interactive plot is finished it looks like this:



When the interactive plot is closed it is rendered as a 3D radial plot like this:



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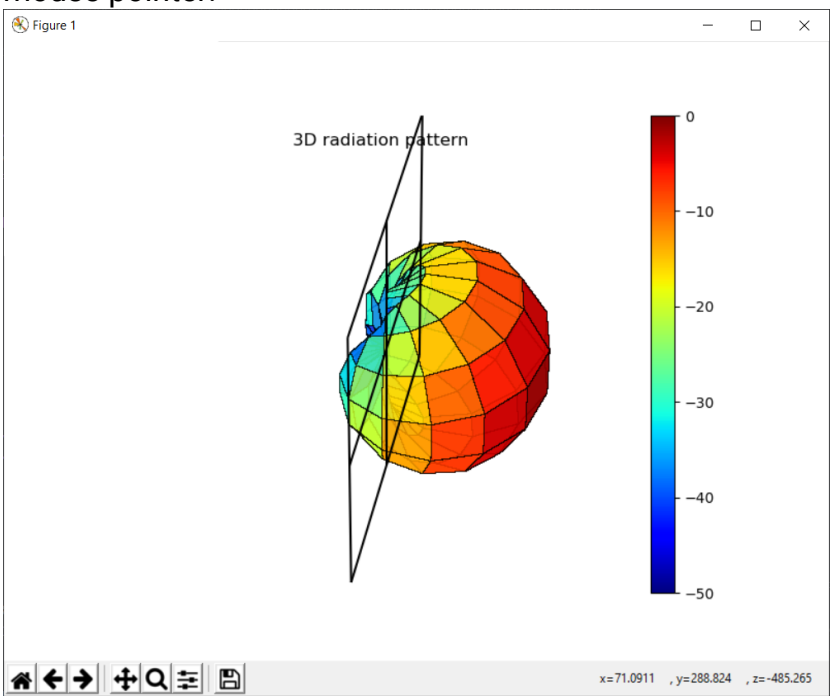
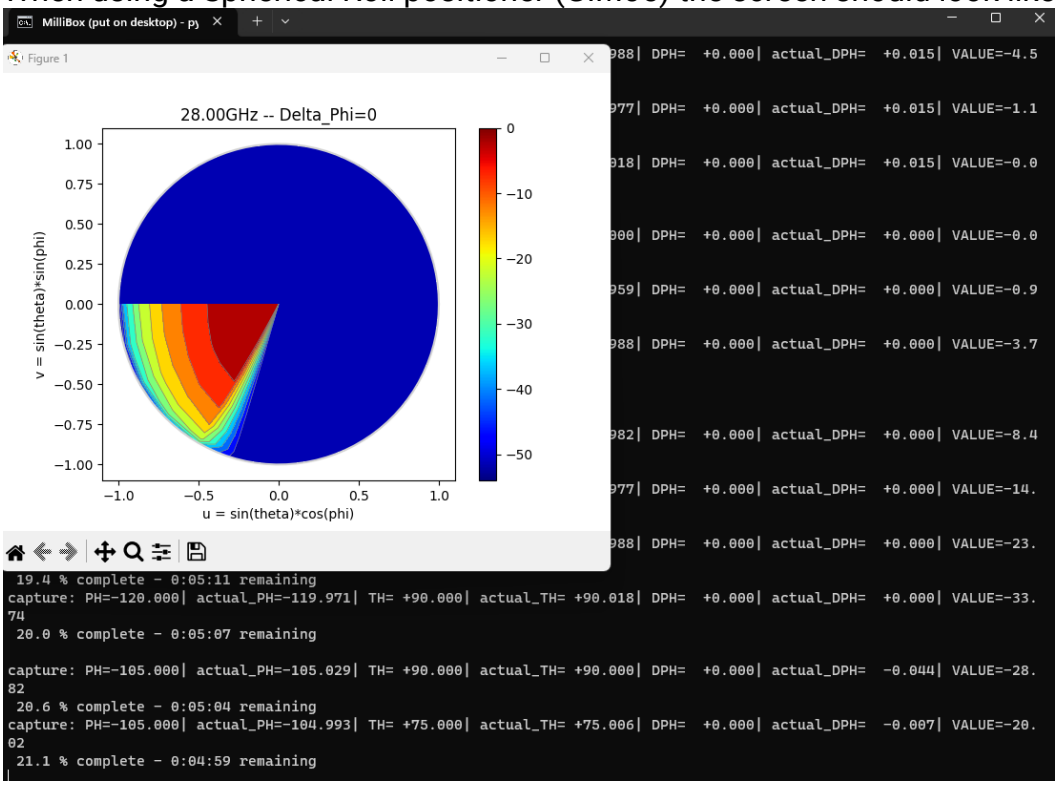
This plot can be moved in all directions for closer inspection with the menu and/or the mouse pointer:



When using a Spherical Roll positioner (GIM05) the screen should look like this:



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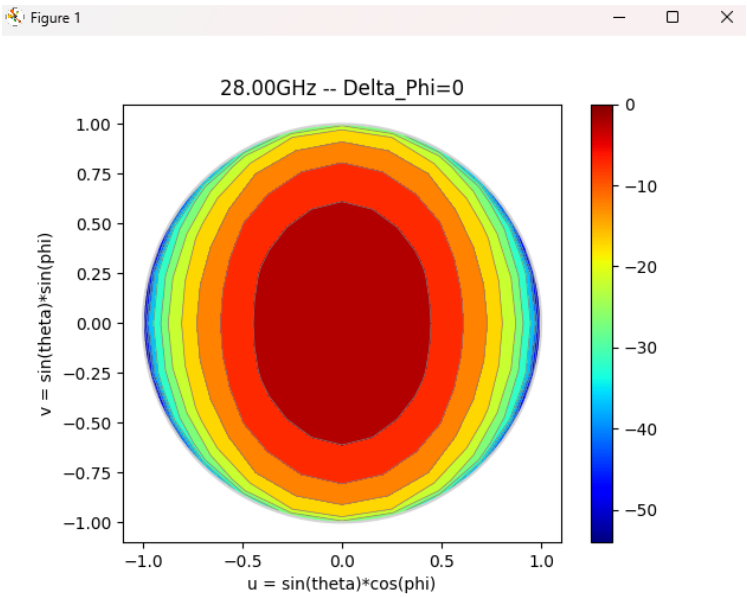
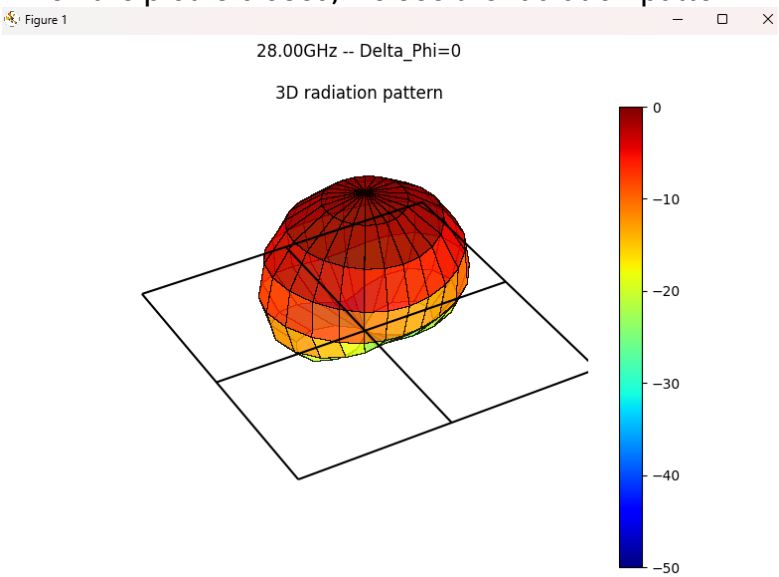
When the default plot concludes and everything worked well we can see the following direction cosine graph:



When the plot is closed, we see the radiation pattern in 3D:



We can inspect this 3D radiation pattern using the mouse pointer and moving the rending around.

At this point we know all the key software components we need are well installed and working and so is communication with the 3D positioner hardware. We can now configure the other side, the measurement instrument.

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Instrument connection and measurement capture.

To establish a connection between mbx software and any instrument, you need key elements.

- A VISA driver for your instrument installed on the machine.
- A physical connection, traditionally, USB, LAN or GPIB
- A VISA address identifying your instrument.

You can obtain support from your instrument vendor to learn how to get these.

One common way to achieve this is to use National Instrument's Measurement and Automation Explorer (MAX) which is part of NI-VISA which can be found here:

https://www.ni.com/en-us/support/downloads/drivers/download.ni-visa.html

First power on your instrument or instruments and set them up as if you had to perform a manual measurement for your DUT. In the case of a spectrum analyzer, we set the center frequency, span, RBW and VBW, then we set a Marker 1 at the measurement frequency. On the Signal Generator we set the power and the same measurement frequency and turn the RF on.

On a VNA we want to set our S12 on Trace 1, select its start, and stop frequencies, frequency step size, as well as our power level. Additionally, we'll have to store the calibration file on the VNA hard drive.

The calibration file is usually stored on the instrument like C:\MILLIBOX\MBX.xyz. where xyz is the file format type and depend by manufacturer. This calibration file name and location are specified in the mbx_instrument.py driver.

Physically, your instrument should be connected to the machine running mbx.py code. This is usually done by either USB connection, TCP/IP networking or through a GPIB dongle. Those physical connections are enabled by installing a VISA driver which allows the machine to send VISA type commands to the instrument to control and query it.

When your instrument is connected and has its VISA driver in place, there are two ways you can determine its VISA resource name.

Use the vendor driver interface to locate the VISA resource name of your instrument. In our example we are using NI-MAX UI and see the address of our spectrum analyzer.

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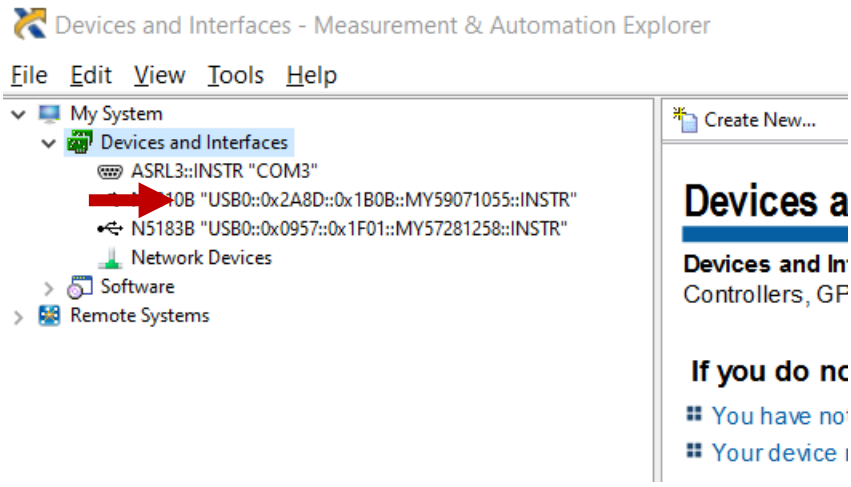

Note: we are also seeing the address of our signal generator shown as "N5183B" make sure you have the address of the instrument you intend to use for measurement.

Run mbx.py and use the function 'y' which lists all the registered addresses on the machine and shows one that is your instrument VISA address.

```
y

Current measurement mode = SA

************* MEASUREMENT SETUP *************
* press <0> for No Instrument
* press <1> for Spectrum Analyzer only
* press <2> for SigGen + Spectrum Analyzer
* press <3> for VNA (mag)
* press <4> for VNA (mag/phase)
* press <ESC> for no change
*********************************************
```

At this time, we can select the measurement setup that most corresponds to our setup: For this example, we have a Signal Generator and a Spectrum Analyzer and want to synchronize the control of both, so we press 2 when prompted.

```
Sig Gen + Spectrum Analyzer mode selected


Select SIG GEN VISA address

************** INSTRUMENT LIST **************
  >>>    1) SIMULATION
         2) MANUAL ENTRY (SIMULATION)
         3) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
         4) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
         5) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
         6) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
*********************************************

Select instrument or enter <0> for no change:
```


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Here the software shows the addresses of the two instruments found on the VISA ports. We are prompted to choose the signal generator within the selector. From the address we recognize that the signal generator is at `N5183B` so we type '3' at the prompt

```
Select SIG GEN VISA address

************** INSTRUMENT LIST **************
  >>>   1) SIMULATION
        2) MANUAL ENTRY (SIMULATION)
        3) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
        4) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
        5) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
        6) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
*********************************************

Select instrument or enter <0> for no change: 3

Measurement instrument selected (addr): TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
```

Confirmation is shown that we selected the proper instrument as our Signal Generator, now the menu asks for the Spectrum analyzer address. We type '5' at the prompt to select our spectrum analyzer.

```
Select SPECTRUM ANALYZER VISA address

************** INSTRUMENT LIST **************
  >>>   1) SIMULATION
        2) MANUAL ENTRY (SIMULATION)
        3) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
        4) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
        5) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
        6) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
*********************************************

Select instrument or enter <0> for no change: 5

Measurement instrument selected (addr): TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
IDN = ['AGILENT TECHNOLOGIES', 'N5183B', 'MY57281258', 'B.01.86']
Found!!
['SG', 'AGILENT*', 'N5183*', <mbx_instrument.SG_Keysight_MXG object at 0x0000019159C7CD90>]
SG CONNECTED: 'AGILENT TECHNOLOGIES N5183B'
IDN = ['KEYSIGHT TECHNOLOGIES', 'N9010B', 'MY59071055', 'A.25.05']
Found!!
['SA', 'KEYSIGHT*', 'N9010*', <mbx_instrument.SA_Keysight_EXA object at 0x0000019159C3BEB0>]
SA CONNECTED: 'KEYSIGHT TECHNOLOGIES N9010B'
initializing equipment
measurement mode and equipment saved to file
```

The software interface shows us the instruments we have selected and their properties. It shows that the proper drivers have been found in `mbx_instrument.py`. Also note that this selection is stored in a file called `mbx.cfg` in the directory where `mbx.py` resides, this way you don't have to select your instrument setup anymore.

Then the main menu shows on screen with the correct instrument setting:

```
************************************************
*
*       Mode: SG+SA
* Instrument: ['TCPIP0::A-N5183B-28125B.laurent::hislip0::INSTR', 'TCPIP0::KA-N9010B-71055.laurent::hislip0::INSTR']
*  Save Corr: ---
*     Zigzag: True
*   Position: (0.00, 0.00, 0.00)
*
************* MAIN MENU *************************
************* USE KEYBOARD ************************
```

We can see the Mode, Instrument, Accuracy and Position are reported correctly.

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A quick check at this point is to call “x” key on the keyboard which will call Marker 1 of the Spectrum Analyzer

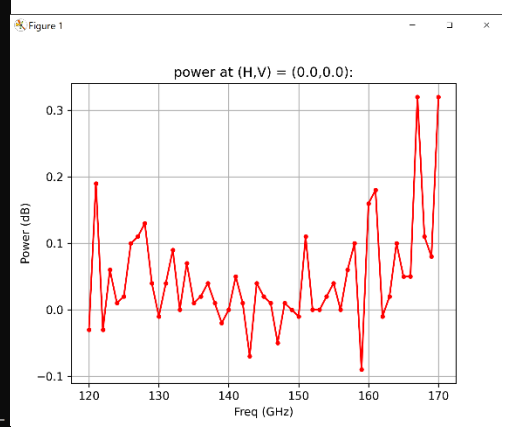
```
*****************************************************
x
power at (H,V) = (0.0,0.0):
  40.00GHz :   -57.21

*****************************************************
*
```

We can see that `-57.21 dB` is the marker 1 value reported on the screen of our Spectrum Analyzer. This confirms our communication between the mbx code and the instrument we installed is working fine.

On a VNA, calling x will look like this:

```
126.00GHz :    0.10
127.00GHz :    0.11
128.00GHz :    0.13
129.00GHz :    0.04
130.00GHz :   -0.01
131.00GHz :    0.04
132.00GHz :    0.09
133.00GHz :   -0.00
134.00GHz :    0.07
135.00GHz :    0.01
136.00GHz :    0.02
137.00GHz :    0.04
138.00GHz :    0.01
139.00GHz :   -0.02
140.00GHz :    0.00
141.00GHz :    0.05
142.00GHz :    0.01
143.00GHz :   -0.07
144.00GHz :    0.04
145.00GHz :    0.02
146.00GHz :    0.01
147.00GHz :   -0.05
148.00GHz :    0.01
149.00GHz :    0.00
150.00GHz :   -0.01
151.00GHz :    0.11
152.00GHz :   -0.00
153.00GHz :    0.00
154.00GHz :    0.02
155.00GHz :    0.04
156.00GHz :   -0.00
157.00GHz :    0.06
158.00GHz :    0.10
159.00GHz :   -0.09
160.00GHz :    0.16
161.00GHz :    0.18
162.00GHz :   -0.01
163.00GHz :    0.02
164.00GHz :    0.10
165.00GHz :    0.05
166.00GHz :    0.05
167.00GHz :    0.32
168.00GHz :    0.11
169.00GHz :    0.08
170.00GHz :    0.32
----------CLOSE PLOT GRAPHIC TO RETURN TO MENU----------
```



Note: Instrument manufacturers have many models which work with the existing drivers. To register your model with the driver in most instances you just need to add your actual model number to the instrument whitelist in `mbx_instrument.py`. In some case you may have to create a new instrument or create a new driver. Those procedures are explained in detail in the section here: New instrument integration strategy

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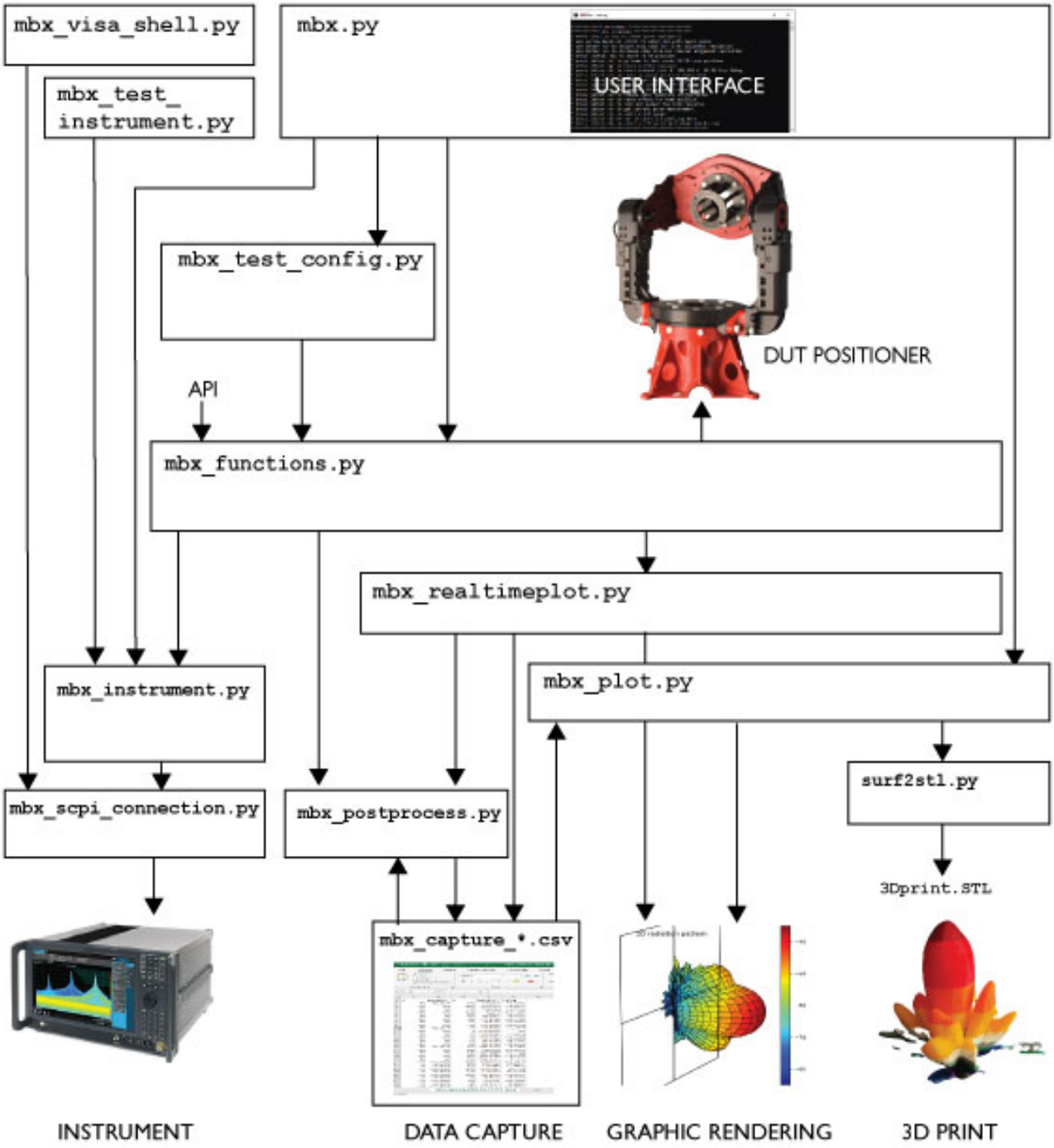
Software hierarchy and principle

Flow chart:



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Software Components:

The 3D positioner Controller is composed of 12 main files and a directory with the low-level motor control:

`dynamixel_functions.py` is the link and selector to the older version of the Dynamixel SDK which is used up to version 23.1 to communicate with the gimbal's motors. It remains in the codebase for legacy reasons, so it is not accessed during typical usage. It will be removed in version 25.

`dynamixel_sdk/` is the python package containing the current version of the Dynamixel SDK, which is used to communicate with the gimbal's motors. This is the driver to the positioner motors which is used from version 24 onward.

`mbx.py` is the entry point to the controller and displays the User Interface (UI).
Upon execution, mbx.py first opens the communication with the 3D positioner then initializes and configures the 3D positioner for operation, then instantiates the instrument. When the initialization is complete mbx.py displays the main menu.
The main menu is a list of keyboard strokes that activate specific functions.
All the functions that mbx.py calls are implemented in mbx_functions.py

`mbx_functions.py` is a collection of all the functions and features that the 3D positioner supports.
First it enumerates all the motor registers and the low-level functions to access the motor registers, then it defines and lists the catalogue of higher-level functions which are called by the UI in `mbx.py` or by `mbx_functions.py` itself.
When it comes to instrument control and graphic rendering, `mbx_functions.py` calls mbx_instrument.py and mbx_realtimeplot.py respectively.
When it performs plot functions, mbx_functions.py creates and fills unique capture files in *.csv format ready for post-processing.
The capture files are stored in the directory:
C:\SWMilliBox\MilliBox_plot_data

`mbx_instrument.py` contains the basic initialization of the VISA communication between mbx_functions.py and the drivers for various instruments. It defines instruments as class, where each class has its set of features and capabilities. This gives the flexibility to support many instruments with various capabilities without impacting the main functions of the 3D positioner itself. This is one area where the user can augment the features of the measurement to the limit of the instrument capabilities. This is also where the user could add new interfaces to new instruments and collect more metrics, for example if one wanted to measure temperature or current consumption of the Device Under Test (DUT) it would be easily scalable to that end.

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Upon instantiation the software will query the instrument ID and try to figure if one of the existing drivers exists. If the driver is positively identified from the ID, then the driver is automatically loaded. If it is not, you can manually add your instrument ID to the driver whitelist featured at the end of the file.

`mbx_plot.py` is a standalone application that is used to graphically display existing captured dataset and sample plots in various rendition modes, like 3D surface, line, heatmap etc. It also connects to **`surf2stl.py`** to offer the creation of a 3D printable STL file.

`mbx_postprocess.py` is the file that contains the resource for post processing existing captured datasets. For example, it allows the application of calibration data to sweeps and addition of two orthogonal sweeps into one non-polarized resulting dataset.

`mbx_realtimeplot.py` contains all the graphic functions for interactive display and post rendering graphics. It features several plot types which can be used readily.

`mbx_scpi_connection.py` is an abstraction layer between VISA and the instrument which supports VXI or SOCKET interfaces. VXI is used when the PC is connected to a Physical instrument. SOCKET is used when MilliBox controller and the Software instrument are installed on the same machine. In this later case the controller and the instrument are physically the same PC and the SCPI commands are communicated through the SOCKET protocol between two software applications running on the same machine.

`mbx_test_config.py` is a simple wrapper which combines the sweep characteristics with other metrics like frequency and instrument type into a coherent call to `mbx_functions.py`. It also offers the capabilities of making more complex test campaigns where capture delay and frequency range can be set for repetitive sweeps.

`mbx_test_instrument.py` is a standalone diagnostic VISA command application which tests compatibility of an instrument against drivers implemented in `mbx_instrument.py`. This is a necessary check to add a new instrument signature to the instrument whitelist.

`mbx_visa_shell.py` is a standalone VISA command interface which allows prototyping and testing any commands for any instrument. This is useful when adding new functionalities to the test setup or adding new instruments for which no drivers are currently implemented.

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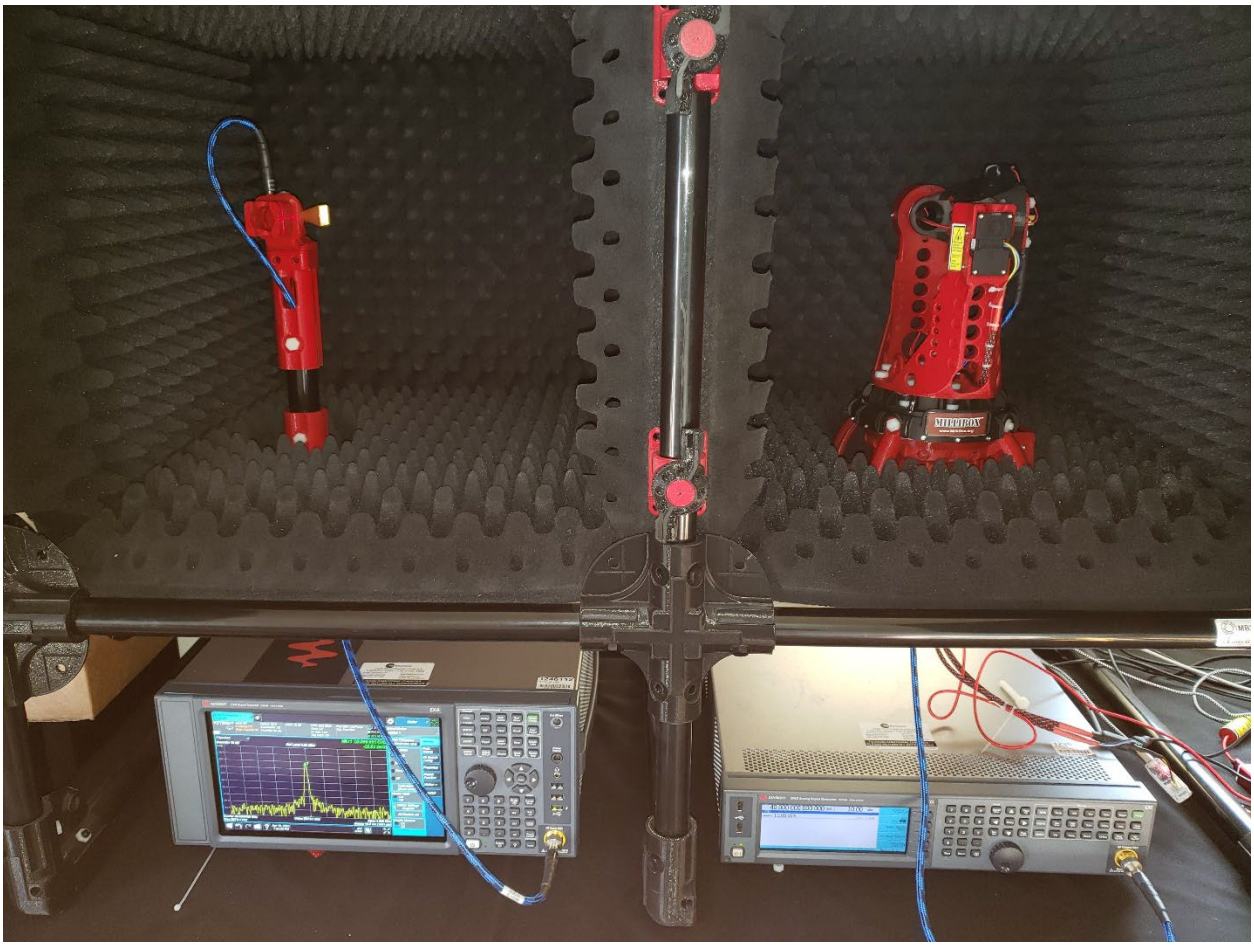
`surf2stl.py` is a program which takes surface shapes and converts them to .stl type file..stl files are stereolithography objects which can be converted to .gcode by a 3D printer parser.

Test Setup:

This is what a typical setup should look like:



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Normal Operations

Menu Header:

Every time the system returns to the Main Menu the Menu Header is displayed:

```
**************************************************
*
*       Mode: NONE
* Instrument: ['SIMULATION']
*  Corr File: ---
*  Save Corr: ---
*     Zigzag: True
*   Position: (0.00, 0.00, 0.00)
*
```

This header shows the current operating status:

- The instrument mode,
- The instrument selected,
- Whether correction factors are applied,
- The correction table file name (if applied),
- Whether a copy of the correction table (if applied) is saved when data is collected,
- Whether ZigZag pattern is used or not,
- The current Gimbal position.

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Main Menu:

The top menu when mbx.py is launched looks like this:

```
************* MAIN MENU *************************
************ USE KEYBOARD ************************
* Press <ESC> or <q> to close ports and quit!
__________ MOVEMENT/ALIGNMENT __________
* use <arrow keys> or <ijkl> to adjust H and V angles
* use <[> or <]> to adjust polarization angle
* use <a> to reduce step size for finer alignment resolution
* use <s> to increase step size for coarser alignment resolution
* press <ZERO> key to store H0 V0 P0 position
* press <h> to go home to last saved H0 V0 P0 home position
* press <m> to open the direct move travel menu
* press <b> to start electronic beam alignment
* press <.> to print current position
_________ GIM MOTION SETTINGS __________
* press <g> to display GIM motion parameters
* press <v> to open the velocity setting menu
* press <r> to open the accel limit setting menu
* press <t> to open the angle limit setting menu
* press <e> to toggle accuracy setting
* press <w> to reset GIM parameters to default
__________ MEASUREMENT SETUP ___________
* press <y> to set measurement mode (VNA/SG+SA/SA/NONE) and set
equipment VISA address
* press <x> to get current power measurement
* press <n> to save current power measurement to file
* press <o> to display correction factor menu
* press <f> to force instrument re-initialization
__________ MEASUREMENT SWEEPS __________
* press <d> to start default plot H -90 90 V -90 90 Step 15deg
* press <c> to start accuracy position check menu
* press <z> to toggle zigzag movement mode for 2D sweeps
* press <1> to start a 1-D sweep
* press <2> to start a 2-D sweep
* press <3> to start a 1-D sweep in E-plane and H-plane
_________ DATA POST-PROCESSING _________
* press <p> to plot from previous measurement
* press </> to display post-processing menu
___________ SPECIAL SETTINGS ___________
* press <:> to change motor baudrate configuration
* press <+> to reset offset for home position
* press <\> to toggle test menu
*********************************************************
```


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The Main Menu and subsequent Sub-Menus use letter keys from the keyboard to operate.

Note that the user interface is optimized for a window 160 characters wide x 60 characters tall. Some output may be missed at different resolutions.

ESC or 'q' key

The keyboard ESC or 'q' key will ask for confirmation, return the positioner to its HOME position, prompt whether the torque on the positioner should be enabled or disabled, terminate mbx.py script and close the COM ports.

```
************************************************************
Quit program? [Y/N]
going to zero position

Disable TORQUE on motors? [Y/N]
disabling torque on all motors
torque now disabled for motor 1
torque now disabled for motor 2

exit called bye bye!

C:\SWMilliBox\MBX\python>
```

The question of whether to disable the torque on the motors is important because if the torque stays enabled the motor will keep working at keeping the position for as long as the positioner is powered on. Not only does this consume power, but this also wears out the motors faster than necessary if they are not intended to be used when mbx.py is closed. On the other hand, one may want to keep the positioner in place while restarting mbx.py or changing some other setups. In this situation the torque on the motor can be maintained.

Note: abort is done with the combination of Ctrl+C in the command shell
Note: avoid removing power or closing mbx.py shell while the positioner is not in the HOME position, as you may lose your HOME position references.

MOVEMENT/ALIGNMENT section:

use <arrow keys> or <ijkl> to adjust H and V angles

The up-down-right-left arrows key and the i, j, k, l, keys of the keyboard are used for manual step motions. They will move the 3D positioner one step size in the direction of the arrow. The default step size is 11.25°

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When you press the up key or “i”
This is what the console shows.

```
up

**************
```

If you press down key or “k” on the keyboard

```
down

***********
```

This is what you see on the console.

The same happens with the right and left keyboard keys or “j” and “l” keys.

Note: to avoid wire tangles the 3D positioner is limited to a total of 180° in both axis in both directions. When using manual step motion, the console will indicate that it hit the boundary in that direction and will not perform the move in that direction anymore. To force this motion the user can hit the ENTER key to reset the null position and extend the 180° limit from here.

Variation for **GIM1D**: only left and right arrow keys as well as j and l are used to operate this positioner.

Variation for **GIM05**: the right and left arrows as well as j and l keys are driving Theta motor (in the base). The up and down arrows as well as the i and k keys are driving the Phi motor in synchronized move of the motor in the positioner hand and the motor in the horn post,

use <[> or <]> to adjust polarization angle

This menu is only shown when 3 axes are present.
Variation for **GIM04x**: the open bracket and closed bracket keys [and] are used to move the polarization angle when equipped.

For **GIM05** [and] keys are driving the horn post motor independently from the positioner Phi motor. And the { and } keys are driving the Phi motor in the positioner independently from the horn post position.

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use <a> to reduce step size for finer alignment resolution

and

use <s> to increase step size for coarser alignment resolution

The ‘a’ and ‘s’ keys are respectively dividers and multipliers of the step size used in manual step motion mode.
Each time the ‘a’ key is pressed the step size is divided by 2.
Each time the ‘s’ key is pressed the step size is multiplied by 2.
This allows to move the 3D positioner position both coarsely when needed and precisely otherwise.

From a default setting at boot-up, if you press the “a” key on the keyboard:

```
a
step size is now: 5.625
```

The initial step size of 11.25° has been divided by 2.

When you press “s” key on the keyboard twice:

```
s
step size is now: 22.5
```

Now the initial value of 11.25° is multiplied by 2.

These keys are used for the manual alignment of the 3D positioner with the Horn post with the laser. Start with a coarse step and as you get closer reduce the step size until the laser is perfectly aligned.

press <ZERO> key to store H0 V0 P0 position

The “0” key is very important since it will reprogram all motors internal flash center offset parameters. This function is a critical element of the calibration routine.
Whenever the “0” key is pressed while in main menu, the current position of the 3D positioner motor will take this position as the home position and the center of the radiation pattern.

☛ Note: This cannot be undone, it can only be overwritten.

The goal is to use the arrow keys or ijkl key of the keyboard to align the laser then press “0” to commit this position to the 3D positioner motor as the boresight position.
Using the “.” key we can print our current position and see how it becomes our home (0,0) position:

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```
Current position for motor 1  is =  11.250074074074075 degree, Position is : 37969 steps,  Offset is : -1439
Current position for motor 2  is =  11.25 degree, Position is : 2176 steps,  Offset is : 3019
Current position for motor 4  is =  0.0 degree, Position is : 2048 steps,  Offset is : -747
************************************************************
motor=1   led=1   offset= -1439   goalpos= 37969   drmode=0
motor=2   led=1   offset=  3019   goalpos=  2176   drmode=0
motor=4   led=1   offset=  -747   goalpos=  2048   drmode=0
************************************************************
```

When we press “0” key on the keyboard:
We are prompted to confirm that the current position of the positioner will become our new Home position.
If we press “Y” to confirm then, the Home position has changed:

```
Save position as new HOME? [Y/N]
current offset= -1439
torque now disabled for motor 1
new offset= -39408
check new offset= -39408
torque now enabled for motor 1
current offset= 3019
torque now disabled for motor 2
new offset= 2891
check new offset= 2891
torque now enabled for motor 2
current offset= -747
torque now disabled for motor 4
new offset= -747
check new offset= -747
torque now enabled for motor 4
going to zero position
this position is now HOME position
```

when you press “.” key again
You can see that the offset position has changed such that our current position is now 0,0,0

```
Current position for motor 1  is =  0.0 degree, Position is : 0 steps,  Offset is : -39408
Current position for motor 2  is =  0.0 degree, Position is : 2048 steps,  Offset is : 2891
Current position for motor 4  is =  0.0 degree, Position is : 2048 steps,  Offset is : -747
************************************************************
motor=1   led=1   offset=-39408   goalpos=     0   drmode=0
motor=2   led=1   offset=  2891   goalpos=  2048   drmode=0
motor=4   led=1   offset=  -747   goalpos=  2048   drmode=0
************************************************************
```

Note: the step to degree conversion for the motors is:
Motor V which has no gear ratio: 0° is 2048 steps, -180° is 0 step and +180 is 4095 steps.
Motor H for GIM01/03/1D/04/05 which has a 5:1 gear ratio: 0° is 2048 steps, -180° is -18,432 steps and +180 is 22,528 step
Motor H for GIM04H and GIM05H which has 2:1 gear ratio: 0° is 0 step, -180° is -607,500 steps and +180 is 607,500 steps.
Motor P of X-Pol which has a 3:1 gear ratio: 0° is 2048 step, -180° is -10,240 steps and +180 is 14,336 steps.

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Note: when the “0” key is pressed, the flash of the motors is written. For the access to flash to happen, the torques of the motors are temporarily disabled. When torque is disabled the 3D positioner position may move when under load. The calibrated position is recorded in software before the torque is disabled, so even if the 3D positioner moves, the calibrated position is not lost.

press <h> to go home to last saved H0 V0 P0 home position

The ‘h’ key is the “go home” key, it will control the 3D positioner to move directly to the calibrated center position, in our case (0°,0°,0°) i.e. (0 steps, 2048 steps, 2048 steps) as we have seen earlier.

```
h
go to 0 position
 travel time was : 0.332 seconds
```

This position is the absolute reference for any subsequent motion, so it is important that it is set correctly.
It is strongly recommended that any test sequence completion finishes at home position.

Note: you should always park the 3D positioner in the home position before unplugging power.
Note: When and only when power is unplugged, you may move the 3D positioner slowly by hand, this can make the 3D positioner lose its home position. It is always strongly recommended to use the arrow keys to move the 3D positioner and avoid turning it by hand.

press <m> to open the direct move travel menu

The ‘m’ key is used to move the 3D positioner to any point in space in H and V plane. The menu asks for the H plane coordinate and the V plane coordinate, then, when the space bar is pressed the movement will be made. The target positions are limited to +/-180° by default or to the position limiter values and are in absolute from the (0,0) home position. The travel time in seconds is printed on the log console.

Note: the position (-90°, 0°) is useful to get the 3D positioner platform facing the MilliBox door, for example when one wants to attach a DUT

Note: this function is useful to measure step travel time under load and can be used in conjunction with the ‘v’ key to determine a velocity needed to achieve a specific step time.

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Note: the time stamps are computed from reading the tick time of the operating system, the communication introduces some latency.

Using velocity setting and direct move settings, for on-the-fly captures:
One way to plot radiation pattern very quickly is just to let the 3D positioner move from angle A to angle B and measure on the fly the changes, for example of output power.
If you know the time it takes for the gimbal to go from angle A to angle B (using “m” key)
And you can regulate this travel time accurately using the “v” key, then you could get your instrument to capture snapshot values at regular time interval as the 3D positioner moves.

This presents the advantage of not having to stop and go at every step and can proceed smoothly without interruption. Also, it does not require synchronization software with the instrument.

In this example we stay on 0° elevation and are only moving Azimuth
We start from center (0,0)
Upon pressing “m” and setting arbitrary values -90°, 0°
We press the Space Bar on the keyboard which means “START”

```
m
Enter targeted angle in horizontal plane in degree: -90
Enter targeted angle in vertical plane in degree: 0
Enter targeted angle in polarization plane in degree: 0

## Please make sure everything is ready to start measurement ##
#####      Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
 travel time was : 1.864 seconds
```

We see that the travel time is 1,864 milliseconds.
Now we use “m” to move the opposite way from -90° to +90°

```
m
Enter targeted angle in horizontal plane in degree: 90
Enter targeted angle in vertical plane in degree: 0
Enter targeted angle in polarization plane in degree: 0

## Please make sure everything is ready to start measurement ##
#####      Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
 travel time was : 2.881 seconds
```

We see that the travel time is 2,881 milliseconds.
Now we use the “v” key to set the max velocity to 1 RPM

```
v
H velocity is set to = 14.60 rpm
V velocity is set to = 234.27 rpm
P velocity is set to = 97.61 rpm
Enter your desired rotation velocity for H in RPM (0=maximum, BLANK=14.6 (no change)): 1
Enter your desired rotation velocity for V in RPM: (0=maximum, BLANK=234.267 (no change)): 1
Enter your desired rotation velocity for P in RPM: (0=maximum, BLANK=97.6112 (no change)): 1
H velocity is set to = 1.00 rpm
V velocity is set to = 0.92 rpm
P velocity is set to = 0.95 rpm
gimbal motion settings saved to mbx.cfg
```


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Now we can do another sweep from 90° to -90° with velocity set at 1 RPM

```
*****************************************************
m
Enter targeted angle in horizontal plane in degree: -90
Enter targeted angle in vertical plane in degree: 0
Enter targeted angle in polarization plane in degree: 0

## Please make sure everything is ready to start measurement ##
#####      Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
 travel time was : 30.156 seconds
```

We see that travel time is significantly longer with 30,156 milliseconds.

Since we know the travel time with relatively good accuracy, we can set our instrument to capture at regular intervals and based on timing reconstruct the radiation pattern.

This is an alternate method which is more manual than a regular synchronized plot. But in some cases, it can be useful.

☛ Note: motors have acceleration and deceleration limits from a stand-still start position to the point where they are running at the dictated velocity target and from full velocity to a stop point. This induces some ramp-up and ramp down time delays.

press <b> to start electronic beam alignment

The ‘b’ key is used as an electronic and automatic way to find the boresight alignment position. When the range is far and an instrument is present to make measurement and the DUT is known to be beaming straight, then this method is the most accurate to determine the true alignment of the positioner to the probe.

☛ Note that when a 3 axis system is used, for instance GIM04 with X-Pol or GIM05, the polarization of the DUT in case of GIM04 and the probe on the horn post in the case of GIM05 <u>must be manually and visually aligned</u> before using the auto-align function.

Upon pressing the ‘b’ key, the warning prompt appears such that the space bar will trigger automatic search for the boresight direction.

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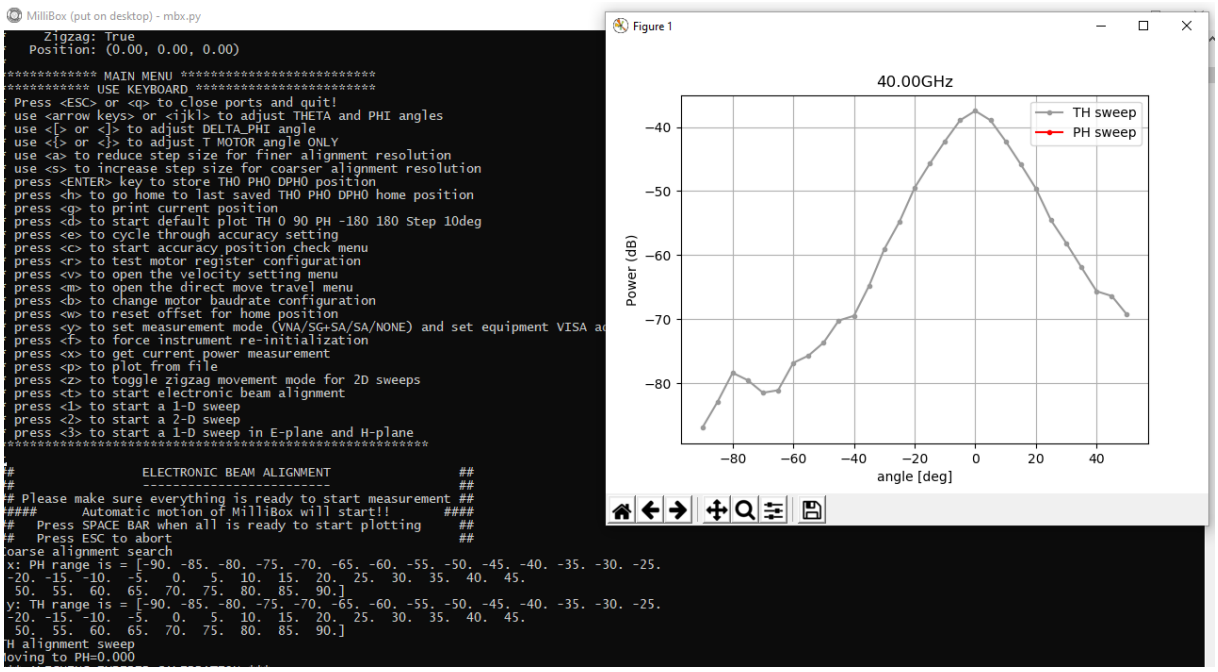
```
t
##                    ELECTRONIC BEAM ALIGNMENT                    ##
##                    -------------------------                    ##
## Please make sure everything is ready to start measurement ##
#####       Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
```

The algorithm uses a two-pass method to reach a conclusive aligned position. The first pass is wider and coarse, then the second pass is narrower in scope but finer.



This shows the first pass with GIM05 in this example.

Then the second pass proceeds automatically…

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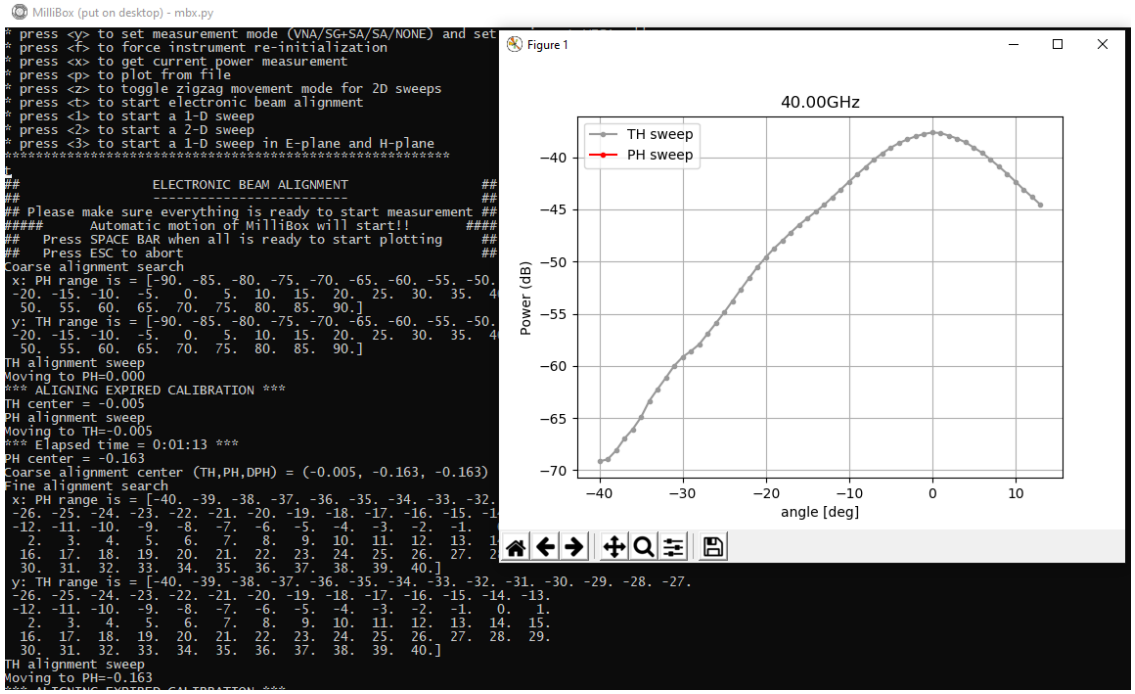
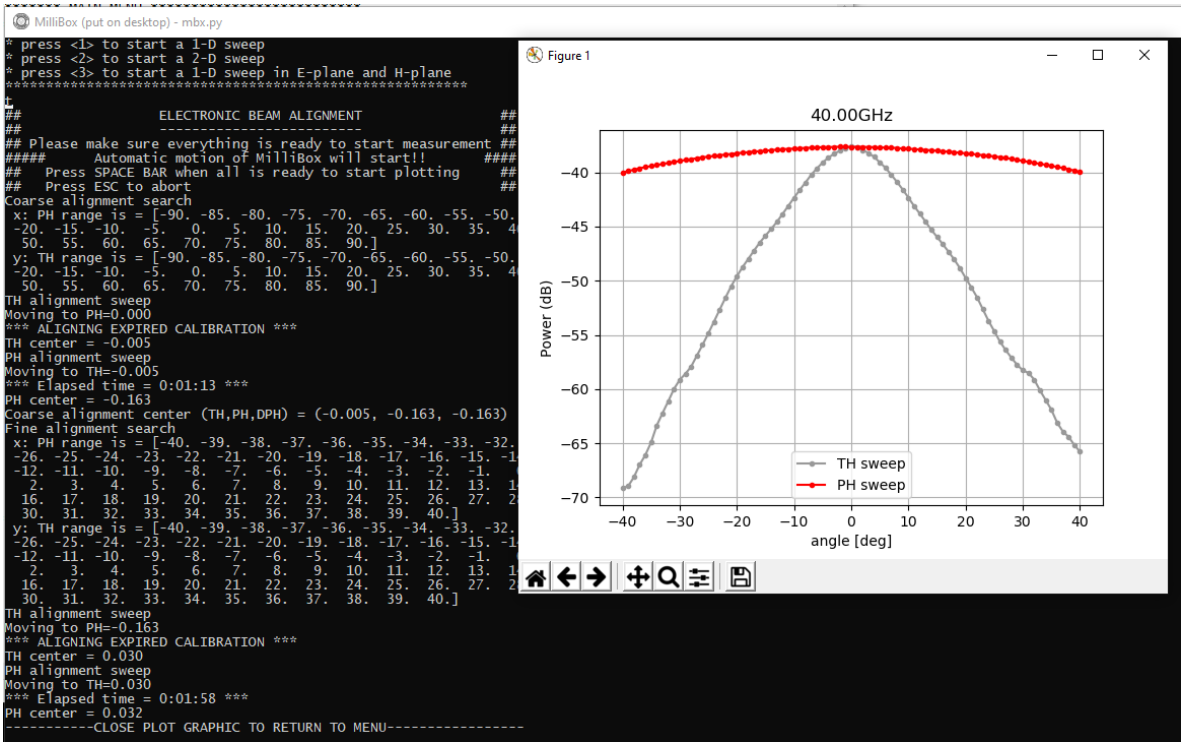


… and finishes with the two axes being aligned. The prompt asks to close the plot window to go back to the menu.



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When the boresight auto-find is completed, the user is prompted to commit the current position as (0,0) or discard it. Committing the current position as (0,0) position is the same as using the “ZERO” key, it will change the Motor Offset register in flash and will be permanent. It can be overwritten as many times as you need but it can’t be undone.

```
H center = 0.083
V alignment sweep
Moving to H=0.083
*** Elapsed time = 0:01:42 ***
V center = 0.022
----------CLOSE PLOT GRAPHIC TO RETURN TO MENU----------------
Fine alignment center (H,V) = (0.083, 0.022)


*****************************************
**** ELECTRONIC BEAM ALIGNMENT RESULT ****
*****************************************

        (H,V) = (0.083, 0.022)

Save position as new HOME? [Y/N]
```

press <.> to print current position

The ‘.’ key is used for debug and prints the current absolute position in motor steps.
By convention:
Motor 1 is called H and move in the horizontal plane or Azimuth or Theta
Motor 2 (and 3 for GIM03/GIM04) is called V and move in the vertical plane or Elevation
Motor 4 (in GIM04 X-Pol) is called P and moves around the Polarization axis
Motor 5 (in GIM05) is called T and rotates the DUT on its radiation axis
Motor 6 (in GIM05 Horn Post) is called Z and rotates the probe on its radiation axis.

H motor on GIM01/1D/03/06 has 20,480 steps per 360° i.e., an absolute step size of 0.0175°
H motor on GIM04 and GIM05 has 1,215,000 steps per 360° i.e., an absolute step size of 0.00029°
V motor has 4,096 steps per 360° i.e., an absolute step size of 0.088°
P motor on X-Pol of GIM04 has 12,288steps per 360° with a step size of 0.029°
T motor on GIM05 has 12,288steps per 360° with a step size of 0.029°
Z motor on GIM05 Horn post has 8,192 steps per 360° with a step size of 0.044°

Upon pressing “.” key on the keyboard:

```
Current position for motor 1  is =  0.0 degree, Position is : 0 steps,  Offset is : -1438
Current position for motor 2  is =  0.0 degree, Position is : 2048 steps,  Offset is : 3019
Current position for motor 4  is =  0.0 degree, Position is : 2048 steps,  Offset is : -747
************************************************************
motor=1   led=1   offset= -1438   goalpos=     0   drmode=0
motor=2   led=1   offset=  3019   goalpos=  2048   drmode=0
motor=4   led=1   offset=  -747   goalpos=  2048   drmode=0
************************************************************
```

Note for GIM1D: only the current position of motor 1 is shown.

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Note for GIM04 with X-Pol: the position of motor 4 representing polarization position is shown in addition to motor 1 and 2.
Note that GIM05 has 3 virtual Motors 101 and 105 and 106, 101 is H Motor, 105 is PH motor and 106 is DPH motor. Those are reported when '.' key is called.

GIM MOTION SETTINGS section:

press <g> to display GIM motion parameters

The "g" key allows for the display of the current settings applied to each motors present on the positioner.

```
g
****** GIM motion settings ******
    gim_type = 1
  num_motors = 4
    accuracy = HIGH
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500, 'anglelim': [-180, 180]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10, 'anglelim': [-180, 180]}
           4 = {'model': 1150, 'vel': 97.61125, 'accel': 20, 'anglelim': [-180, 180]}
```

It shows the model IDs of the motors, the velocity target, the acceleration limit and the angle limiter.
Those values are read from the file mbx.cfg, which stores the motor setting on the computer hard drive. As such the Gimbal configuration values set by the user are retained through power cycles on this users' machine.

Note: Motor 3, even if present (like in GIM03 and GIM04), is never shown because it is a physical "mirror slave" of Motor 2

The motion velocity profile of the motors is a trapezoidal pattern, torque is applied up to the acceleration limit, until target velocity is reached, then when the area of target position is near, the torque decelerates to the acceleration limit until it reaches its destination.

Limiting acceleration is desired when the DUT load is heavier, and the positioner shakes at stop and start of motion.

The angle limiter is useful when an obstacle is present on the possible motion path, and the user chooses to make this obstacle unreachable, even incidentally, to prevent damage to the positioner or the DUT. An obstacle in this case can be a wire, a probe, or any intrusion in the motion area.

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press <v> to open the velocity setting menu

Pressing the “v” key on the keyboard opens the interactive velocity configuration menu for each motor present.

```
v
H velocity is set to = 14.60 rpm
V velocity is set to = 234.27 rpm
P velocity is set to = 97.61 rpm
Enter your desired rotation velocity for H in RPM (0=maximum, BLANK=14.6 (no change)): |
```

Here you can set 0 for maximum velocity, nothing (BLANK) to make no changes, or any other numerical value.
Here we set 25 to motor H which exceeds the maximum velocity of 14.6 rpm, therefore the value of 14.6 rpm is maintained.
We set a value of 0.2 RPM on V which is rounded to the register resolution to 0.23 rpm.
We set a value of 0 on P, which means maximum and the velocity stays at 97.61 rpm.

```
v
H velocity is set to = 14.60 rpm
V velocity is set to = 234.27 rpm
P velocity is set to = 97.61 rpm
Enter your desired rotation velocity for H in RPM (0=maximum, BLANK=14.6 (no change)): 25
Enter your desired rotation velocity for V in RPM: (0=maximum, BLANK=234.267 (no change)): 0.2
Enter your desired rotation velocity for P in RPM: (0=maximum, BLANK=97.6112 (no change)): 0
clamping to maximum possible velocity for H motor
H velocity is set to = 14.60 rpm
V velocity is set to = 0.23 rpm
P velocity is set to = 97.61 rpm
gimbal motion settings saved to mbx.cfg
```

In some cases, it is useful to do synchronized motion on all axis, in this case the same rpm value is set for all motors:

```
v
H velocity is set to = 14.60 rpm
V velocity is set to = 0.23 rpm
P velocity is set to = 97.61 rpm
Enter your desired rotation velocity for H in RPM (0=maximum, BLANK=14.6 (no change)): 2.5
Enter your desired rotation velocity for V in RPM: (0=maximum, BLANK=0.229 (no change)): 2.5
Enter your desired rotation velocity for P in RPM: (0=maximum, BLANK=97.6112 (no change)): 2.5
H velocity is set to = 2.50 rpm
V velocity is set to = 2.52 rpm
P velocity is set to = 2.48 rpm
gimbal motion settings saved to mbx.cfg
```

Then we can use the “m” key to execute a synchronized move on all axes. Look at the “m” key description to read how synchronized motion can be used for on-the-fly captures.

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These user settings are recorded in the configuration file mbx.cfg, which is retained on the user's hard drive over power cycles.

Note: There is no guarantee that the motor can reach the maximum velocity which can be set in the motor register. In the example above, the maximum velocity on motor V is 234.27 rpm since it is the maximum value which can be set in the registers but there is no possibility of this motor reaching this speed.

press <r> to open the accel limit setting menu

Pressing the "r" key on the keyboard opens the interactive acceleration limit configuration menu for each motor present.

```
r
H accel is set to = 2500
V accel is set to = 10
P accel is set to = 20
Enter your desired acceleration limit for H (0=set to default, BLANK=2500 (no change)):
```

Setting an acceleration limit for the motor is nothing more than using a torque limiter, which dictates the time it takes for the motor to reach its maximum velocity or its destination.
Limiting the acceleration and therefore the torque relieves stress on the mechanical structures and gears of the positioner. It becomes more critical to limit acceleration as the weight of the load on the positioner increases.

The motion velocity profile of the motors is a trapezoidal pattern, torque is applied up to the acceleration limit, until target velocity is reached, then when the area of target position is near, the torque decelerates to the acceleration limit until it reaches its destination.

Here we set some values for each motor

```
r
H accel is set to = 2500
V accel is set to = 10
P accel is set to = 20
Enter your desired acceleration limit for H (0=set to default, BLANK=2500 (no change)): 3000
Enter your desired acceleration limit for V (0=set to default, BLANK=10 (no change)): 0
Enter your desired acceleration limit for P (0=set to default, BLANK=20 (no change)):
*** H accel limit set ***
*** V accel limit set ***
*** P accel limit set ***
H accel is set to = 3000
V accel is set to = 10
P accel is set to = 20
gimbal motion settings saved to mbx.cfg
```


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Here, we could increase the acceleration value on motor H beyond the 2000 default limit to 3000, this will make the motion harsher and increase stress on the positioner, but it is accepted by the software.
We set 0 on motor V to set back to default value of 10 for this motor.
We set nothing on motor P, which means that we did not touch this value which stays 20.

Note: The register values for each motor acceleration limit are not related due to motor type and gear ratio, so in our case 3000 on this motor H may be about the same acceleration as 10 on motor V. Instead look at the default value to get a sense of scale for this motor and don't look at other motor values.

These user settings are recorded in the configuration file mbx.cfg, which is retained on the user's hard drive over power cycles, and re-loaded when mbx.py is launched.

These user settings are configured to default values at the factory and don't have to be touched in most cases.

press <t> to open the angle limit setting menu

Pressing the "t" key on the keyboard opens the interactive menu for angle limiter.
If it happens that because of mechanical limitation on the DUT or wiring of the DUT, some angles should not be reached to prevent mechanical collision, then this angle limiter comes in handy.

```
t
H angle limit is set to [-180.0, 180.0]
V angle limit is set to [-180.0, 180.0]
P angle limit is set to [-180.0, 180.0]

Current H angle limit = [-180.0, 180.0]
Enter your desired lower angle limit for H (BLANK=-180 (no change)): |
```

Here you can enter any value between -180 and +180 if the lower limit is smaller than the higher limit. If you don't enter anything, the current value is retained. The angle limit must also have 0° as a valid point so that Home position is a valid position.

These user settings are recorded in the configuration file mbx.cfg, which is retained on the user's hard drive over power cycles and re-loaded when mbx.py is launched.

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```
t
H angle limit is set to [-180.0, 180.0]
V angle limit is set to [-180.0, 180.0]
P angle limit is set to [-180.0, 180.0]

Current H angle limit = [-180.0, 180.0]
Enter your desired lower angle limit for H (BLANK=-180 (no change)): -40
Enter your desired upper angle limit for H (BLANK=180 (no change)): 40
*** H angle limit set ***

Current V angle limit = [-180.0, 180.0]
Enter your desired lower angle limit for V (BLANK=-180 (no change)):
Enter your desired upper angle limit for V (BLANK=180 (no change)):
*** V angle limit set ***

Current P angle limit = [-180.0, 180.0]
Enter your desired lower angle limit for P (BLANK=-180 (no change)):
Enter your desired upper angle limit for P (BLANK=180 (no change)):
*** P angle limit set ***
H angle limit is set to [-40.0, 40.0]
V angle limit is set to [-180.0, 180.0]
P angle limit is set to [-180.0, 180.0]
gimbal motion settings saved to mbx.cfg
```

Now let's try to do a direct move to 60 in H.

```
m
Enter targeted angle in horizontal plane in degree: 60
Enter targeted angle in vertical plane in degree: 0
Enter targeted angle in polarization plane in degree: 0

H motor angle target = 60.0000 is out of range [-40.0, 40.0]
*** Movement cancelled ***
```

The move did not happen and was cancelled due to the limit in H.

Now let's see what happened when we want to do a plot beyond the angle limit:

```
2
going to zero position
This is your zero position: center of the plot


************ 2-Axis Sweep ************

Plot display options:
  0 - no interactive plot display
  1 - 3d surface plot
  2 - 2d heatmap plot
  3 - multi-trace line plot
  4 - 3d radiation pattern ONLY

Select the plot display option: 1

Enter your start angle in horizontal plane in degree: -90
Enter your last angle in horizontal plane in degree: 90
Enter your start angle in vertical plane in degree: -90
Enter your last angle in vertical plane in degree: 90
Enter your step size in degree : 15
Enter your polarization position in degree : 0


#######################################################################
##    ERROR :  THOSE VALUES CAN'T PLOT, Please try other values    ##
#######################################################################


Re-enter sweep parameters? [Y/N]
```


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Here the plot can't start, but we are invited to enter new parameters:

```
Re-enter sweep parameters? [Y/N]

Enter your start angle in horizontal plane in degree: -40
Enter your last angle in horizontal plane in degree: 40
Enter your start angle in vertical plane in degree: -90
Enter your last angle in vertical plane in degree: 90
Enter your step size in degree : 15
Enter your polarization position in degree : 0

Enter a tag to append to filename or [ENTER] for no tag:


Enter the freq [GHz] to plot: 28
## Please make sure everything is ready to start measurement ##
#####      Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
Measurement delay = 0 msec
 Plot data is saved in file : ..\..\MilliBox_plot_data\mbx_capture_2023-10-12-163514_2d_.csv

**** Plotting frequency = 28.000GHz ****

 V range is = [-90. -75. -60. -45. -30. -15.   0.  15.  30.  45.  60.  75.  90.]
 H range is = [-40. -25. -10.   5.  20.  35.]
capture: V= -90.000| actual_V= -90.000| H= -40.000| actual_H= -40.001| P=  +0.000| actual_P=  +0.000| VALUE=
 ... ]
  1.3 % complete - 0:04:32 remaining
```

When we enter values which fit in the limits then our plot can proceed.

This angle limiter value prevented us from going past an angle we blocked, either by a direct move or by automatic move during a plot.

press <e> to toggle accuracy setting

When the "e" key is pressed, it moves to the next accuracy mode. By default, the mode is set to "HIGH" accuracy mode. When "e" is pressed we move to the next accuracy mode "VERY HIGH"

```
e
Gimbal accuracy setting = VERY HIGH
****** GIM motion settings ******
    gim_type = 1
  num_motors = 4
    accuracy = VERY HIGH
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500, 'anglelim': [-180.0, 180.0]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10, 'anglelim': [-180.0, 180.0]}
           4 = {'model': 1150, 'vel': 97.61125, 'accel': 20, 'anglelim': [-180.0, 180.0]}
gimbal motion settings saved to mbx.cfg
```

When "e" is pressed again we move back to the accuracy mode "HIGH"

```
e
Gimbal accuracy setting = HIGH
****** GIM motion settings ******
    gim_type = 1
  num_motors = 4
    accuracy = HIGH
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500, 'anglelim': [-180.0, 180.0]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10, 'anglelim': [-180.0, 180.0]}
           4 = {'model': 1150, 'vel': 97.61125, 'accel': 20, 'anglelim': [-180.0, 180.0]}
gimbal motion settings saved to mbx.cfg
```


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- HIGH ensures current position is within accuracy threshold of goal position.
- VERY HIGH additionally uses hysteresis on all motors - overshoot in one direction and always come back to target from same direction such that the variation in gear backlash is minimized for every step in any direction. This is also important when the measuring step size is << 1°.

press <w> to reset GIM parameters to default

The “w” key can be used to reset all the positioner user settings to factory default. It can also be used to erase the saved port and baudrate from mbx.cfg, which will trigger an autoscan the next time mbx.py is run.

```
*********************************************************
w
Reset GIM motion control parameters to default? [Y/N]
H model is = 2000
V model is = 1140
****** GIM motion settings ******
           1 = {'anglelim': [-180, 180], 'model': 2000, 'vel': 14.6, 'accel': 2500}
           2 = {'anglelim': [-180, 180], 'model': 1140, 'vel': 234.267, 'accel': 10}
  num_motors = 3
    gim_type = 1
    accuracy = HIGH
gimbal motion settings saved to mbx.cfg
Erase saved port and baudrate? [Y/N]
Saved port and baudrate erased. On next launch, all ports will be scanned.
```


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MEASUREMENT SETUP section:

press <y> to set measurement mode (VNA/SG+SA/SA/NONE) and set equipment VISA address

The ‘y’ key is used to check or configure the test mode we want to use and to select from the available instances of VISA capable instruments found on the current machine.

```
y

Current measurement mode = NONE

************* MEASUREMENT SETUP *************
* press <0> for No Instrument
* press <1> for Spectrum Analyzer only
* press <2> for SigGen + Spectrum Analyzer
* press <3> for VNA (mag)
* press <4> for VNA (mag/phase)
* press <ESC> for no change
*********************************************
```

Here above we see that our current measurement mode is NONE, in this case all plots and sweeps will use simulated value which are not extracted from an actual instrument. This is useful to check that the positioner control is working well irrespective of the instrument setup, or when tests don’t involve instruments.

But if we want to attach an instrument we can choose from 4 configurations

- 1 is for Spectrum analyzer only. This is a very common setup when the DUT is active and generates its own signal.
- 2 is for Signal Generator and Spectrum Analyzer, which is prefered when the DUT is passive and requires a signal input to radiate.
- 3 is a for Vector Network Analyzer setup collecting Magnitude data. This is also very common for passive DUT whenever a S21 measurement can be set. This is powerful because MilliBox software can capture the entire S21 trace at each step of the plot.
- 4 is is a for Vector Network Analyzer setup collecting Magnitude and Phase data.

In our example below we selected mode 1 : SIGGen + Spectrum Analyzer mode, the menu shows the list of instrument connection found automatically. The menu asks us to locate our signal generator address which we selected as 3 in the list. Subsequntly the menu ask us to associate our Spectrum Analyzer in the address list and we selected 5).
When this is done the controller queries the instruments and save the settings.

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```
Select SIG GEN VISA address

************** INSTRUMENT LIST **************
  >>>   1) SIMULATION
        2) MANUAL ENTRY (SIMULATION)
        3) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
        4) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
        5) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
        6) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
**********************************************

Select instrument or enter <0> for no change: 3

Measurement instrument selected (addr): TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR


Select SPECTRUM ANALYZER VISA address

************** INSTRUMENT LIST **************
  >>>   1) SIMULATION
        2) MANUAL ENTRY (SIMULATION)
        3) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
        4) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
        5) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
        6) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
**********************************************

Select instrument or enter <0> for no change: 5

Measurement instrument selected (addr): TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
IDN = ['AGILENT TECHNOLOGIES', 'N5183B', 'MY57281258', 'B.01.86']
Found!!
['SG', 'AGILENT*', 'N5183*', <mbx_instrument.SG_Keysight_MXG object at 0x0000019159C7CD90>]
SG CONNECTED: 'AGILENT TECHNOLOGIES N5183B'
IDN = ['KEYSIGHT TECHNOLOGIES', 'N9010B', 'MY59071055', 'A.25.05']
Found!!
['SA', 'KEYSIGHT*', 'N9010*', <mbx_instrument.SA_Keysight_EXA object at 0x0000019159C3BEB0>]
SA CONNECTED: 'KEYSIGHT TECHNOLOGIES N9010B'
initializing equipment
measurement mode and equipment saved to file
```

Note: this is user's responsibility to make sure that the selected mode and the actual instrument are matching. For example, selecting a Spectrum Analyzer from the list when the mode is set to VNA is not going to work and can possibly break the code execution.

To test that the communication and there is a match between the mode, the instrument and the driver, the 'x' key is useful.

If like below, we had instead a software instrument on our PC, then our controller can't find it automatically, so we press entry 2) for Manual Entry menu:
In our example we use the VNA mode and set the VNA address manually.
When prompted for the instrument address we enter:
TCPIP0::127.0.0.1::5001::SOCKET
Which means port 5001 of the local machine using SOCKET interface.
When this is set, the controller initiates connection with our instrument and loads the calibration files automatically.

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```
************* MEASUREMENT SETUP *************
* press <0> for No Instrument
* press <1> for Spectrum Analyzer only
* press <2> for SigGen + Spectrum Analyzer
* press <3> for VNA
* press <ESC> for no change
*********************************************
VNA mode selected
Select VNA VISA address

************** INSTRUMENT LIST **************
  >>>   1) SIMULATION
        2) MANUAL ENTRY (SIMULATION)
        3) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
        4) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
        5) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
        6) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
*********************************************

Select instrument or enter <0> for no change: 2
Enter equipment VISA address: TCPIP0::127.0.0.1::5001::SOCKET

Measurement instrument selected (addr): TCPIP0::127.0.0.1::5001::SOCKET
IDN = ['ANRITSU', 'MS46122B', '12345', 'V2021.5.2', 'XXXX']
Found!!
['VNA', 'ANRITSU*', 'MS461*', <mbx_instrument.VNA_Anritsu_VectorStar object at 0x0000019159C7C550>]
VNA CONNECTED: 'ANRITSU MS46122B'
initializing equipment

******************** IMPORTANT ********************
  Loading C:\MILLIBOX\MBX.CHX
  Ensure VNA is calibrated, frequencies are set, and
  transmission measurement is on the ACTIVE trace
***************************************************
loading cal file...
setting to logmag...
continuous trigger on...
measurement mode and equipment saved to file
```

press <x> to get current power measurement

The ‘x’ key is used to test the VISA connection and verify that the metric used for radiation pattern capture, level of Marker 1, is correctly accessed and read by the controller software.

This validates that the physical and logical connection between the instrument and the controller are established.

Upon pressing ‘x’ key on the keyboard we see:

```
x
power at (H,V) = (0.0,0.0): -27.26
```

This shows the H,V position and the power measured at this point.

When we move the 3D positioner position using the arrow keys on the keyboard and press ‘x’ again we see:

```
x
power at (H,V) = (20.0,20.3): -46.98

************** MAIN MENU ********************
```

When the setup is used in a VNA setup, the “x” key returns the full trace:

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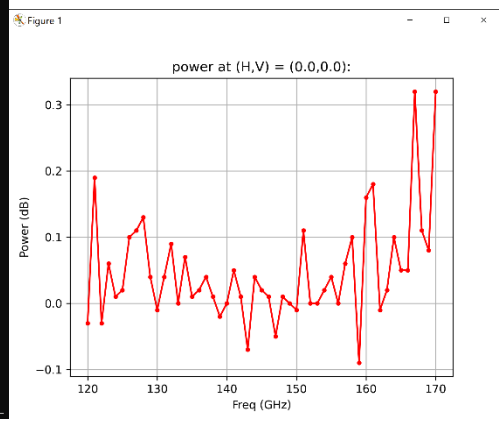
```
126.00GHz :    0.10
127.00GHz :    0.11
128.00GHz :    0.13
129.00GHz :    0.04
130.00GHz :   -0.01
131.00GHz :    0.04
132.00GHz :    0.09
133.00GHz :   -0.00
134.00GHz :    0.07
135.00GHz :    0.01
136.00GHz :    0.02
137.00GHz :    0.04
138.00GHz :    0.01
139.00GHz :   -0.02
140.00GHz :    0.00
141.00GHz :    0.05
142.00GHz :    0.01
143.00GHz :   -0.07
144.00GHz :    0.04
145.00GHz :    0.02
146.00GHz :    0.01
147.00GHz :   -0.05
148.00GHz :    0.01
149.00GHz :    0.00
150.00GHz :   -0.01
151.00GHz :    0.11
152.00GHz :   -0.00
153.00GHz :    0.00
154.00GHz :    0.02
155.00GHz :    0.04
156.00GHz :   -0.00
157.00GHz :    0.06
158.00GHz :    0.10
159.00GHz :   -0.09
160.00GHz :    0.16
161.00GHz :    0.18
162.00GHz :   -0.01
163.00GHz :    0.02
164.00GHz :    0.10
165.00GHz :    0.05
166.00GHz :    0.05
167.00GHz :    0.32
168.00GHz :    0.11
169.00GHz :    0.08
170.00GHz :    0.32
----------CLOSE PLOT GRAPHIC TO RETURN TO MENU----------------
```

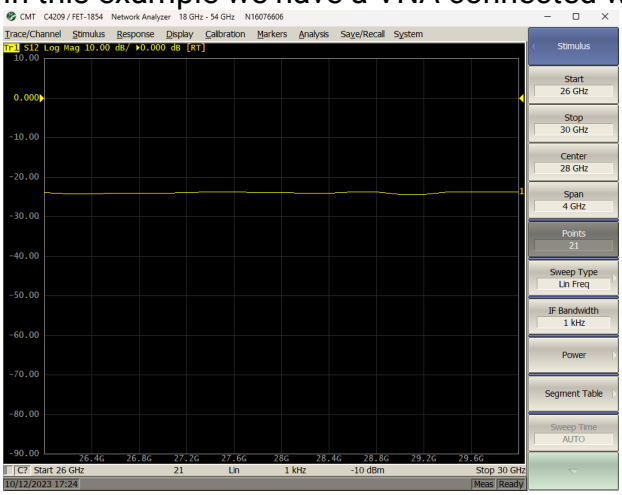


Note: before initiating a plot, it is a good idea to use the “x” key to check that the values captured are the expected one.

press <n> to save current power measurement to file

The “n” key is useful to capture the current data from the instrument to a formatted file. This is a necessary step when applying calibration factor which we will cover for the “o” key below.

In this example we have a VNA connected with the current trace setting:



We see a trace going from 26GHz to 30GHz with 21 points at about -24dB

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We press the “n” key on the keyboard.
We choose the number of consecutive measurements, and the delay between each.
We set the file name as “`our_vna_trace_1`”.

```
n
Number of consecutive measurements: 1
Measuring point 1 of 1

Filename to save or [ENTER] to cancel: our_vna_trace_1

SAVED to ..\..\MilliBox_plot_data\our_vna_trace_1.csv
```

This file is created in “`C:\SWMilliBox\MilliBox_plot_data`” folder:

corr_factor	10/9/2023 12:59 PM	File folder
sample_data	10/9/2023 12:59 PM	File folder
mbx_capture_2023-10-09-161240_2d_def...	10/9/2023 4:15 PM	Microsoft Ex
mbx_capture_2023-10-09-161849_2d_def...	10/9/2023 4:19 PM	Microsoft Ex
mbx_capture_2023-10-12-163055_2d_.csv	10/12/2023 4:31 PM	Microsoft Ex
mbx_capture_2023-10-12-163514_2d_.csv	10/12/2023 4:35 PM	Microsoft Ex
our_vna_trace_1.csv	10/12/2023 5:28 PM	Microsoft Ex

When we open this new file, we see:

A1 ƒx 26

	A	B	C
1	26000000000	-23.97	
2	26200000000	-24.22	
3	26400000000	-24.22	
4	26600000000	-24.07	
5	26800000000	-24.11	
6	27000000000	-24.13	
7	27200000000	-23.88	
8	27400000000	-23.7	
9	27600000000	-23.8	
10	27800000000	-23.99	
11	28000000000	-23.94	
12	28200000000	-24.07	
13	28400000000	-24.06	
14	28600000000	-23.77	
15	28800000000	-23.81	
16	29000000000	-24.36	
17	29200000000	-24.43	
18	29400000000	-23.82	
19	29600000000	-23.8	
20	29800000000	-23.83	
21	30000000000	-23.79	

Which perfectly corresponds to a direct VNA trace capture to file.
This will come handy when applying correction factors to a trace capture.

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press <o> to display correction factor menu

The ‘o’ key opens the correction factor menu which is useful to make absolute or calibrated captures.
The basic recipe is as follows.

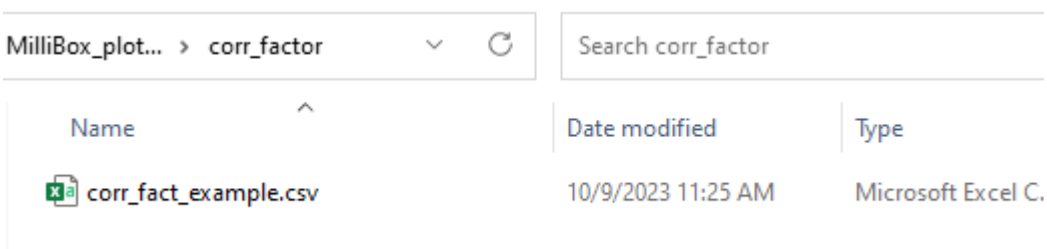
- In place of your DUT use a Standard Gain Horn (SGH) for which you have the datasheet.
- Using everything else exactly the same (coax, probe, etc..) measure this SGH.
- Apply gain factors from the SGH datasheet.
- Create a correction factor file based on this setup.
- Replace the SGH with your DUT.
- Apply the correction factor to your measurements of your DUT, the values are now absolute.

Let’s review the steps with the “o” key menu.

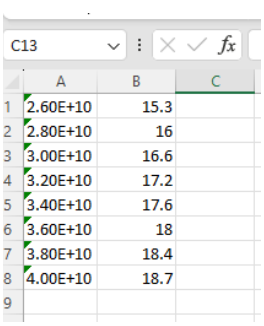
```
o

************* CORRECTION FACTOR MAIN MENU *************
*
*  Corr File: ---
*  Save Corr: ---
*
******************* USE KEYBOARD *********************
* Press <ESC> or <q> to quit corr factor menu
* press <a> to display the current correction factors
* press <b> to load correction factor file
* press <c> to clear the correction factors
* press <d> to toggle saving correction factor with measured data
*******************************************************
```

We start by creating the correction factor of our SGH, for this we navigate to the correction factor directory:
“`C:\SWMilliBox\MilliBox_plot_data\corr_factor`”



And we open the file: “`corr_fact_example.csv`” to see how it is formatted:



	A	B	C
1	2.60E+10	15.3	
2	2.80E+10	16	
3	3.00E+10	16.6	
4	3.20E+10	17.2	
5	3.40E+10	17.6	
6	3.60E+10	18	
7	3.80E+10	18.4	
8	4.00E+10	18.7	
9			

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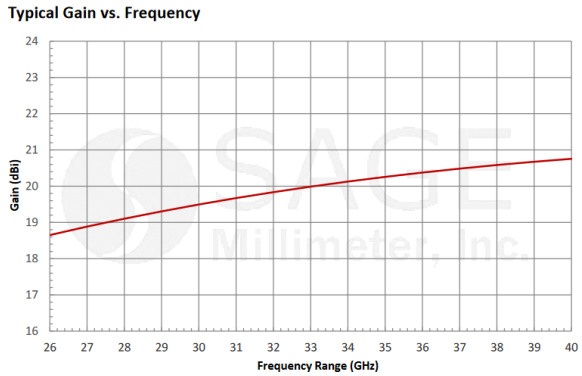
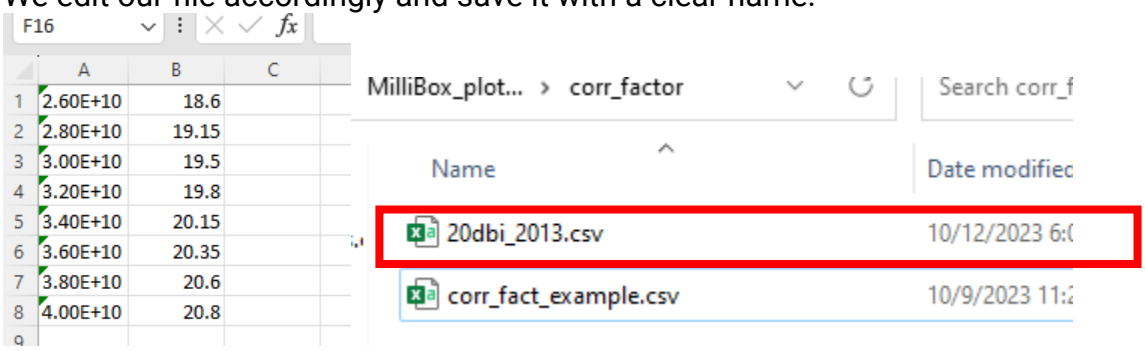
Now we look at the SGH datasheet:



(in this example we use a 20dBi Wr 28 SGH from Eravant: SAR-2013-282F-E2)

We edit our file accordingly and save it with a clear name:



	A	B	C
1	2.60E+10	18.6	
2	2.80E+10	19.15	
3	3.00E+10	19.5	
4	3.20E+10	19.8	
5	3.40E+10	20.15	
6	3.60E+10	20.35	
7	3.80E+10	20.6	
8	4.00E+10	20.8	

Now that we have our seed correction file, we can move to the next step.

We apply this seed correction factor file using the “b” key in the correction factor menu:

```
b

Filename to load or [ENTER] to cancel: 20dbi_2013.csv

Loading correction factor file: ..\..\MilliBox_plot_data\corr_factor\20dbi_2013.csv
```

… and check the correction is applied:

```
************* CORRECTION FACTOR MAIN MENU *************
*
*  Corr File: ..\..\MilliBox_plot_data\corr_factor\20dbi_2013.csv
*  Save Corr: True
*
******************** USE KEYBOARD *********************
* Press <ESC> or <q> to quit corr factor menu
* press <a> to display the current correction factors
* press <b> to load correction factor file
* press <c> to clear the correction factors
* press <d> to toggle saving correction factor with measured data
*******************************************************
```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Now we need to measure our SGH with this correction factor and save it, for this we use the “n” key after leaving the correction factor menu using ESC key.

```
*****************************************************
n
Save <C>orrected data or <R>aw data?
```

Now that we have a correction factor file in place the menu asks us if we want corrected values or raw values. Raw values are those collected directly from the VNA. In our case we want the corrected value and press “c”.

```
*****************************************************
n
Save <C>orrected data or <R>aw data?


Filename to save or [ENTER] to cancel: calibrated_setup.csv
```

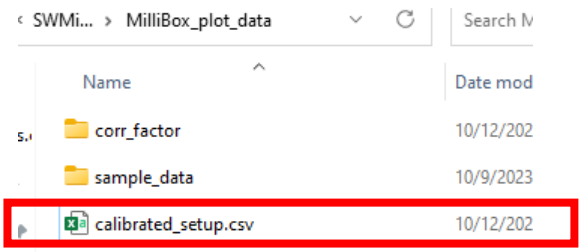
We will create a new file, that we call “`calibrated_setup.csv`”

```
Filename to save or [ENTER] to cancel: calibrated_setup.csv

SAVED to ..\..\MilliBox_plot_data\calibrated_setup.csv

*************************************************
*
*       Mode: VNA
* Instrument: ['TCPIP0::localhost::5025::SOCKET']
*  Corr File: ..\..\MilliBox_plot_data\corr_factor\20dbi_2013.csv
*  Save Corr: True
*     Zigzag: True
*   Position: (0.00, 0.00, 0.00)
```

We look for this file in “C:\SWMilliBox\MilliBox_plot_data”



We now copy this file over to our corr_factor folder:
“`C:\SWMilliBox\MilliBox_plot_data\corr_factor`”

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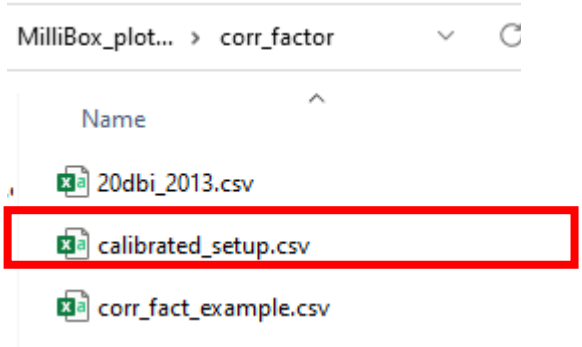

We will now apply the new correction factor file for our setup.
We go back to the “o” menu:

```
o

************* CORRECTION FACTOR MAIN MENU *************
*
*  Corr File: ..\..\MilliBox_plot_data\corr_factor\20dbi_2013.csv
*  Save Corr: True
*
******************* USE KEYBOARD *********************
* Press <ESC> or <q> to quit corr factor menu
* press <a> to display the current correction factors
* press <b> to load correction factor file
* press <c> to clear the correction factors
* press <d> to toggle saving correction factor with measured data
*******************************************************
```

We press “b” to load the new calibrated file:

```
b

Filename to load or [ENTER] to cancel: calibrated_setup.csv

Loading correction factor file: ..\..\MilliBox_plot_data\corr_factor\calibrated_setup.csv


************* CORRECTION FACTOR MAIN MENU *************
*
*  Corr File: ..\..\MilliBox_plot_data\corr_factor\calibrated_setup.csv
*  Save Corr: True
*
******************* USE KEYBOARD *********************
* Press <ESC> or <q> to quit corr factor menu
* press <a> to display the current correction factors
* press <b> to load correction factor file
* press <c> to clear the correction factors
* press <d> to toggle saving correction factor with measured data
*******************************************************
```

Let’s try our setup and see if our setup is calibrated:
For this we go back to the main menu and use key “3” to make our HV plot.

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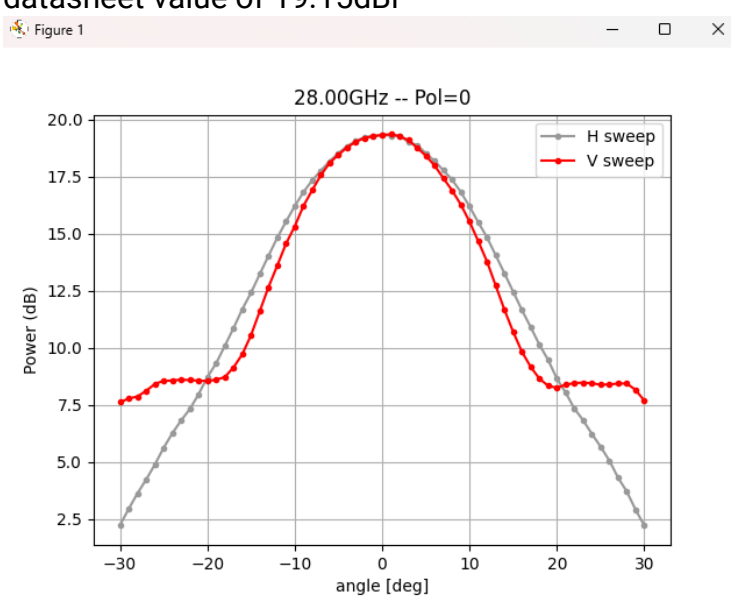
```
3
going to zero position


************ 1-D Single Direction Sweep in E-plane and H-plane ************

Plot display options:
  0 - no interactive plot
  1 - interactive plot

Select the plot display option: 1

Enter your start angle in degree: -30
Enter your last angle in degree: 30
Enter your step size in degree : 1
Enter your polarization position in degree : 0

Enter a tag to append to filename or [ENTER] for no tag: calibrated_check


Enter the freq [GHz] to plot: 28
## Please make sure everything is ready to start measurement ##
#####      Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
```

We get this plot below with a value at 19.18dB at 28GHz: which corresponds to our datasheet value of 19.15dBi



With this setup, we can now replace this SGH with our own DUT and measure our gain directly.

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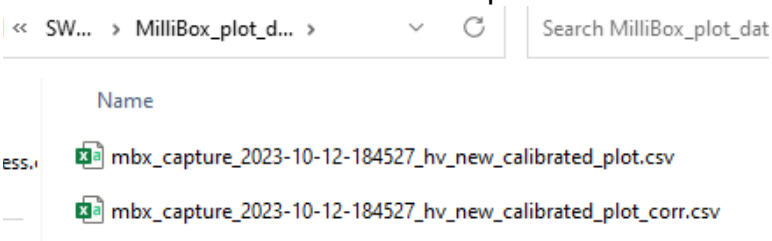
Navigate to "`C:\SWMilliBox\MilliBox_plot_data`" folder and observe that we have now 2 files collected for one plot:



The file "`mbx_capture_2023-10-12-184527_hv_new_calibrated_plot.csv`" contains the plot data with corrected values.
and "`mbx_capture_2023-10-12-184527_hv_new_calibrated_plot_corr.csv`" contains the correction factor table used for this plot.

We can go back to our correction factor menu pressing "o" and in this menu when we press "d" key we can toggle between saving the correction file together with the captured data, or just saving the captured data without saving the correction factor file every time.

```
d
Save Corr with Data = False

************* CORRECTION FACTOR MAIN MENU *************
*
*  Corr File:  \  \MilliBox_plot_data\corr_factor\calibrated_setup.csv
*  Save Corr: False
*
******************** USE KEYBOARD *********************
* Press <ESC> or <q> to quit corr factor menu
* press <a> to display the current correction factors
* press <b> to load correction factor file
* press <c> to clear the correction factors
* press <d> to toggle saving correction factor with measured data
*******************************************************
```

We can also altogether clear the correction factor using the "c" key in the correction factor menu.
This will not delete the correction factor files themselves, it will just not apply its coefficient to the captured data.

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```
c
WARNING: Clear all correction factors? [Y/N]

Clearing correction factors


************* CORRECTION FACTOR MAIN MENU *************
*
*  Corr File: ---
*  Save Corr: ---
*
******************** USE KEYBOARD *********************
* Press <ESC> or <q> to quit corr factor menu
* press <a> to display the current correction factors
* press <b> to load correction factor file
* press <c> to clear the correction factors
* press <d> to toggle saving correction factor with measured data
*******************************************************
```

press <f> to force instrument re-initialization

The ‘f’ key is used to re-initialize the instrument attached in the defined setup. This usually triggers re-calibration of the RF chain of the instrument.

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MEASUREMENT SWEEPS section:

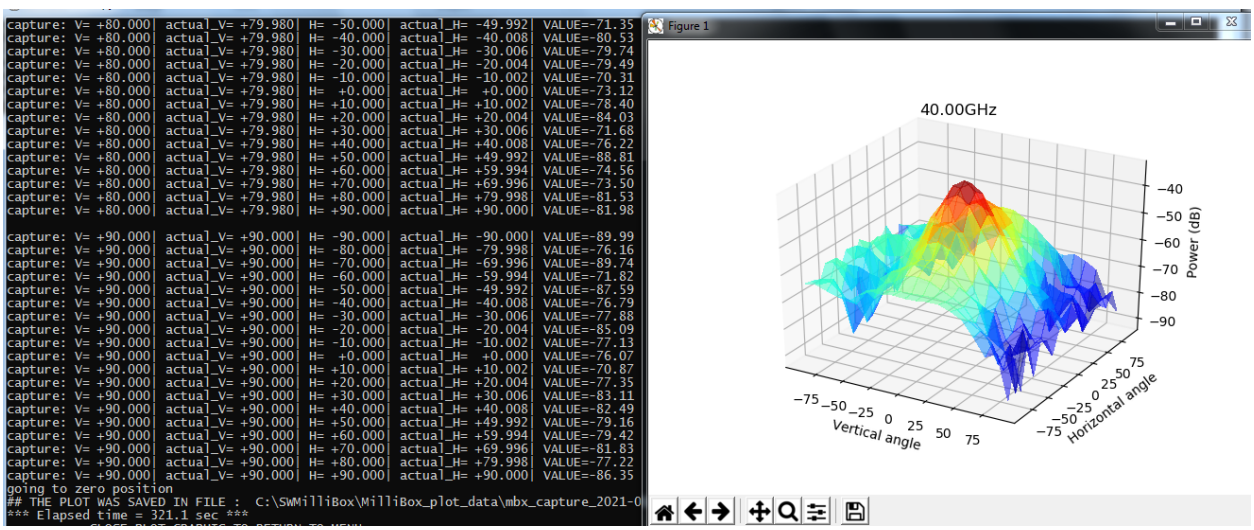
press <d> to start default plot H -90 90 V -90 90 Step 15deg

The “d” key is very useful to quickly perform a trial run plot.
It will plot the default plot: H -90° +90° V-90°+90° in 15° steps.
We recommend using this to test everything is moving and capturing correctly, no wires get in the way etc. before you start a finer pitch plot which can take hours to complete and be ruined by such an incident along the way.

Upon pressing “d” key on the keyboard:

```
d
going to zero position
## Please make sure everything is ready to start measurement ##
#####      Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
```

The warning prints on the console to give you time to close the doors, make sure everything is clear, at this time press the SPACE BAR and the motion of the 3D positioner will start right away and the plot begins. After a few minutes, the plot is complete.



The console shows the location and name of the data file containing the raw data.
When the 3D plot is closed the software will render the plot in a radial 3D view.

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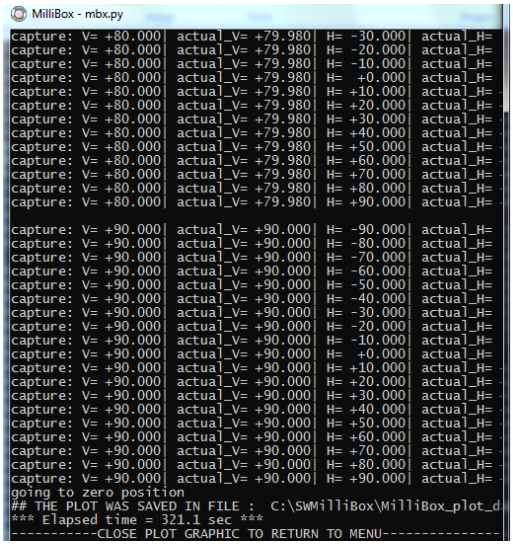

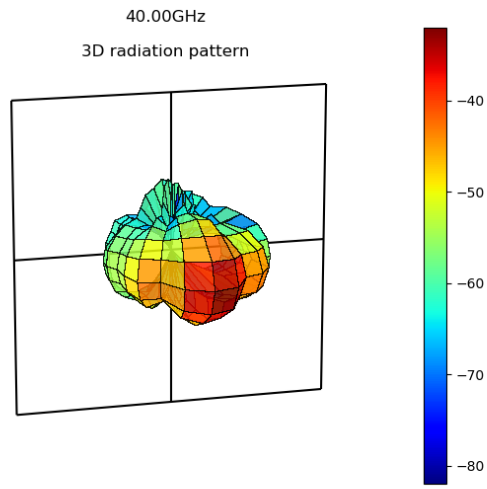

When this 3D radial plot is closed, the software will return to the main menu.

press <c> to start accuracy position check menu

The “c” key is used for test and makes a plot of the delta between target position and actual position. It is used for advanced calibration of PID parameters for different payload and plot step sizes. Use this menu to tweak your PID values depending on your DUT load and velocity.

Upon pressing the “c” key on the keyboard:

```
going to zero position
This is your zero position: center of the plot
Enter your start angle in horizontal plane in degree: -90
Enter your last angle in horizontal plane in degree: 90
Enter your start angle in vertical plane in degree: -90
Enter your last angle in vertical plane in degree: 90
Enter your step size in degree : 20
## Please make sure everything is ready to start measurement ##
#####      Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
```

The plot setting is presented and you have to enter the 5 plot parameters:
Start V, end V angles
Start H, end H angles
And the desired step size
At this point you press the SPACE BAR to get the accuracy plot started:

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```
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -45.00|Hquant= -45.00|actual_H= -45.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -43.00|Hquant= -43.00|actual_H= -43.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -41.00|Hquant= -40.99|actual_H= -40.99|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -39.00|Hquant= -39.01|actual_H= -39.01|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  -0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -37.00|Hquant= -37.00|actual_H= -37.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  -0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -35.00|Hquant= -35.00|actual_H= -35.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -33.00|Hquant= -32.99|actual_H= -32.98|verr=  +0.00|herr=  +0.02|vtoterr=  +0.02|htoterr=  +0.02
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -31.00|Hquant= -31.01|actual_H= -31.01|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  -0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -29.00|Hquant= -29.00|actual_H= -28.99|verr=  +0.00|herr=  +0.02|vtoterr=  +0.02|htoterr=  +0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -27.00|Hquant= -27.00|actual_H= -27.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -25.00|Hquant= -25.00|actual_H= -25.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -23.00|Hquant= -22.99|actual_H= -22.99|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -21.00|Hquant= -21.01|actual_H= -20.99|verr=  +0.00|herr=  +0.02|vtoterr=  +0.02|htoterr=  +0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -19.00|Hquant= -19.00|actual_H= -19.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  -0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -17.00|Hquant= -17.00|actual_H= -17.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -15.00|Hquant= -14.99|actual_H= -14.99|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -13.00|Hquant= -13.01|actual_H= -12.99|verr=  +0.00|herr=  +0.02|vtoterr=  +0.02|htoterr=  +0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H= -11.00|Hquant= -11.00|actual_H= -11.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  -0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H=  -9.00|Hquant=  -9.00|actual_H=  -9.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H=  -7.00|Hquant=  -7.00|actual_H=  -7.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H=  -5.00|Hquant=  -4.99|actual_H=  -4.99|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  +0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H=  -3.00|Hquant=  -3.01|actual_H=  -3.01|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  -0.01
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H=  -1.00|Hquant=  -1.00|actual_H=  -1.00|verr=  +0.00|herr=  +0.00|vtoterr=  +0.02|htoterr=  -0.00
capture: V= +47.00|V_quant= +47.02|actual_V= +47.02|H=  +1.00|Hquant=  +1.00|actual_H=  +1.02|verr=  +0.00|herr=  +0.02|vtoterr=  +0.02|htoterr=  +0.02
```

The console prints the target position, the quantization approximation due to the step size granularity and the recorded variation from target with quant, then records the total error accumulated.
This method uses the integrated absolute position encoders as feedback to acquire the actual position of the motor and compare it to the desired position.
Because there are 4096 steps resolution for one turn, not all positions can be reached beyond 0.1°.
The accuracy plot is recorded in a unique file stored in:
C:\SWMilliBox\MilliBox_plot_data\
Which looks like this:

AutoSave Off mbx_accuracy_2021-01-

File Home Insert Page Layout Formulas Data Review View Add-ins Help

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	1	2	3	4	5	6	7	8	9	10
1	V	Vquant	actual_V	H	Hquant	actual_H	Verr	Herr	Vtoterr	Htoterr
2	-90	-90	-90	-90	-90	-90	0	0	0	0
3	-90	-90	-90	-70	-69.9961	-69.9961	0	0	0	0.003906
4	-90	-90	-90	-50	-49.9922	-49.9922	0	0	0	0.007813
5	-90	-90	-90	-30	-30.0059	-30.0059	0	0	0	-0.00586
6	-90	-90	-90	-10	-10.002	-10.002	0	0	0	-0.00195
7	-90	-90	-90	10	10.00195	10.00195	0	0	0	0.001953
8	-90	-90	-90	30	30.00586	30.00586	0	0	0	0.005859
9	-90	-90	-90	50	49.99219	49.99219	0	0	0	-0.00781
10	-90	-90	-90	70	69.99609	70.01367	0	0.017578	0	0.013672
11	-90	-90	-90	90	90	90	0	0	0	0
12	-70	-69.9609	-69.9609	-90	-90	-90	0	0	0.039063	0
13	-70	-69.9609	-69.9609	-70	-69.9961	-69.9961	0	0	0.039063	0.003906
14	-70	-69.9609	-69.9609	-50	-49.9922	-49.9922	0	0	0.039063	0.007813
15	-70	-69.9609	-69.9609	-30	-30.0059	-30.0059	0	0	0.039063	-0.00586
16	-70	-69.9609	-69.9609	-10	-10.002	-9.98438	0	0.017578	0.039063	0.015625
17	-70	-69.9609	-69.9609	10	10.00195	10.01953	0	0.017578	0.039063	0.019531
18	-70	-69.9609	-69.9609	30	30.00586	30.00586	0	0	0.039063	0.005859
19	-70	-69.9609	-69.9609	50	49.99219	49.99219	0	0	0.039063	-0.00781
20	-70	-69.9609	-69.9609	70	69.99609	69.99609	0	0	0.039063	-0.00391

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Notes: changing PID values of the motors may cause unstable behavior like continuous oscillation and erratic movements which can damage the 3D positioner, this is reserved for advanced users.

press <z> to toggle zigzag movement mode for 2D sweeps

The “z” key is used to toggle the zig-zag plot pattern on and off. Zig-zag is when the positioner does not come back to its starting H (or Theta for GIM05) position, but instead increment the path as a continuous motion. It will move clockwise, then increment the other orthogonal axis then move counterclockwise then increment orthogonal axis and move clockwise again. This type of path saves a lot of time and motions as opposed to the path going only clockwise or counterclockwise only. In most instances it is preferred, but this is an option the user can choose.

Upon pressing the “z” key you’d see:

```
z
Zigzag movement mode = False

**********************************
```

Which means the plot path is standard.

Alternatively, upon pressing the “z” key again you will see:

```
**********************************
z
Zigzag movement mode = True

**********************************
```

Which means the plot path follows the zig-zag pattern.

And so-on as you press the “z” key.

Note: upon the start of mbx.py, the operation is defaulted to zig-zag ON.

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press <1> to start a 1-D sweep

The '1' key is used to execute a 1-D plot. The 1-D plot is a plot where one direction is set and the other sweeps from start angle to stop angle at step size occurrence.

```
************* 1-D Single Direction Sweep *************

Plot display options:
  0 - no interactive plot
  1 - interactive plot

Select the plot display option:
```

Decide if you want a plot which traces on screen as the measurements are made in real time.

```
Select the plot display option: 1

Select sweep direction:
  H - horizontal sweep
  V - vertical sweep
  Q - quit and return to main menu
```

Select whether you want a Horizontal sweep at fixed Vertical angle (press H) or a Vertical sweep at a fixed Horizontal angle (press V)

```
Enter your FIXED angle in vertical plane in degree: 45
Enter your start angle in horizontal plane in degree: -90
Enter your last angle in horizontal plane in degree: 90
Enter your step size in degree : 20
```

Set your fixed angle and the start end angle and step size following the menu.

```
Enter a tag to append to filename or [ENTER] for no tag: _
```

Here you are prompted to enter a label to your plot file name, here I entered "this is a test"

```
Enter a tag to append to filename or [ENTER] for no tag: this is a test
```

This is the last prompt before the 3D positioner is going to spring into action.

```
## Please make sure everything is ready to start measurement ##
#####      Automatic motion of MilliBox will start!!       ####
##   Press SPACE BAR when all is ready to start plotting     ##
##   Press ESC to abort                                      ##
```

This is where you would make sure the laser is OFF and the doors are closed, and no wires have come loose.

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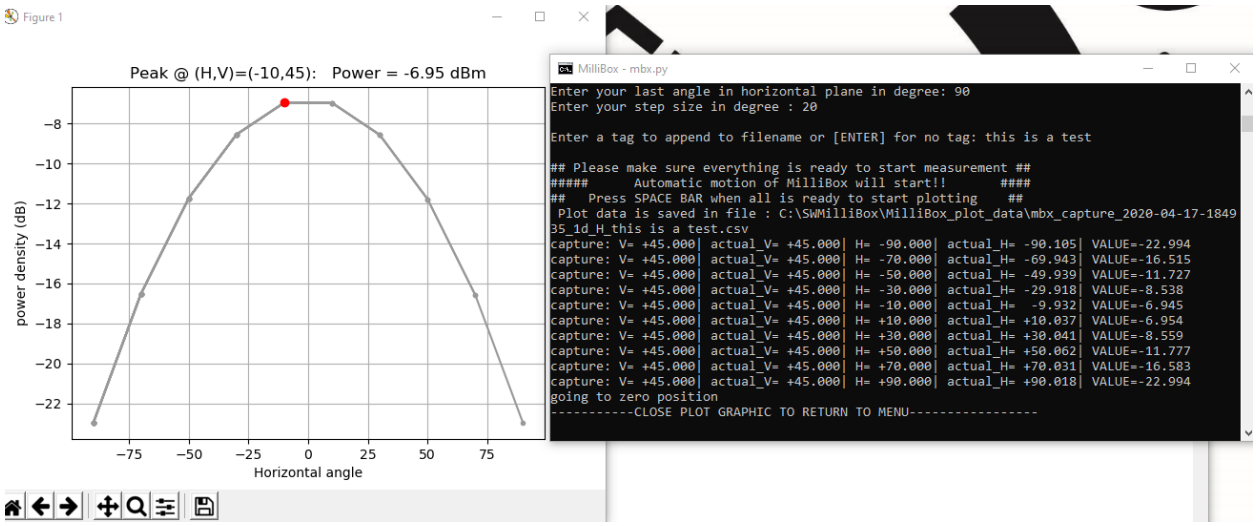
Press Space bar and the motion starts.



This is what appears onscreen, and we can notice several things:
A graph of the plot is created as the 3D positioner moves along the sweep.
We can see on screen the file that was created, in my case the full file path and name was:
C:\SWMilliBox\MilliBox_plot_data\mbx_capture_2020-04-17-184935_1d_H_this is a test.csv
So, we have the path of the capture file the mbx_capture, then the date and time 18:49:35 (in 24h format), the type of plot is 1D in Horizontal plane, then the tag I inserted “this is a test” at this end.
Then we can see the data printed in the command log as it goes along so we can monitor that everything went well.
At the end we are prompted to close the graphic plot to be able to return to the main menu.
This gives us time to save the plot before starting another one.

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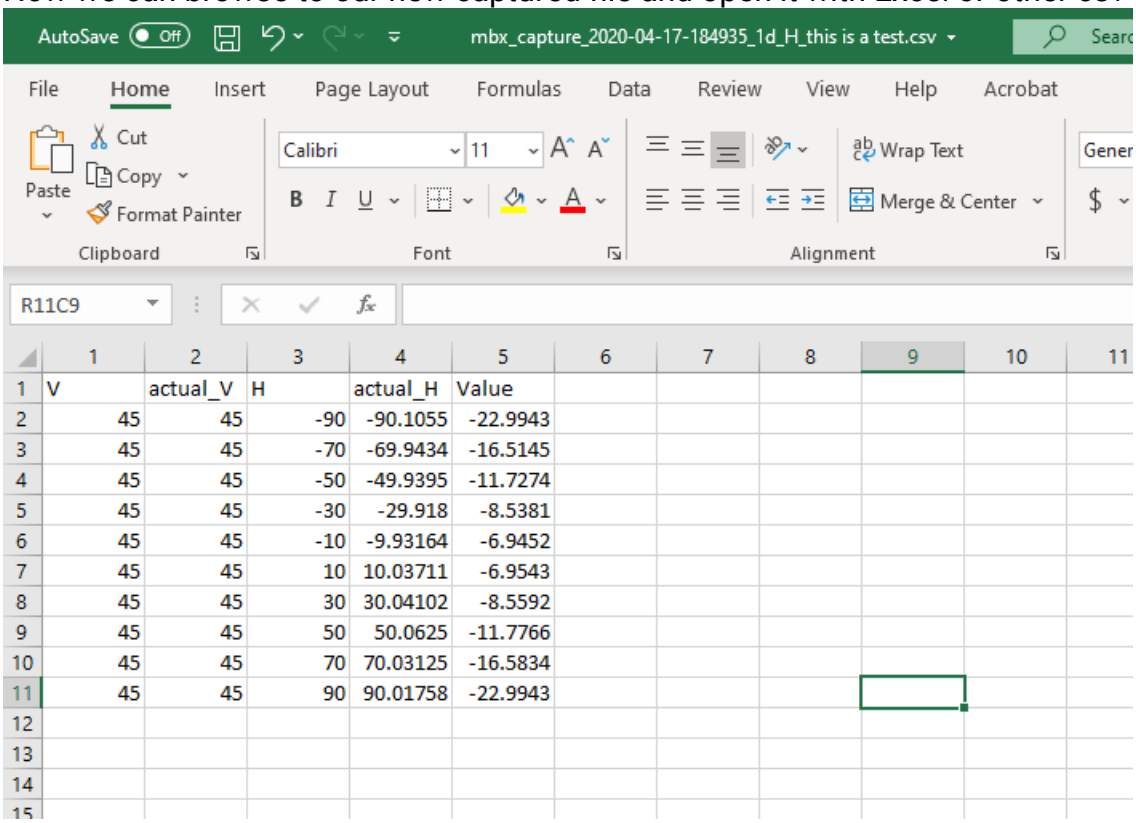
Now we can browse to our new captured file and open it with Excel or other csv editors:



	1	2	3	4	5
1	V	actual_V	H	actual_H	Value
2	45	45	-90	-90.1055	-22.9943
3	45	45	-70	-69.9434	-16.5145
4	45	45	-50	-49.9395	-11.7274
5	45	45	-30	-29.918	-8.5381
6	45	45	-10	-9.93164	-6.9452
7	45	45	10	10.03711	-6.9543
8	45	45	30	30.04102	-8.5592
9	45	45	50	50.0625	-11.7766
10	45	45	70	70.03125	-16.5834
11	45	45	90	90.01758	-22.9943

We see how the data are organized on our captured file, the target angle positions and the actual recorded angle positions from the motor encoders then the column with the value recorded.

Note: in this example we did not have a spectrum analyzer connected so the values are “simulated” those are just mathematically generated values and are not actual measured values, this was just a test…

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press <2> to start a 2-D sweep

The “2” key is used to execute a 2-D plot. Upon pressing the “2” key on the keyboard the first menu appears:

```
************ 2-Axis Sweep ************

Plot display options:
  0 - no interactive plot display
  1 - 3d surface plot
  2 - 2d heatmap plot
  3 - multi-trace line plot
  4 - 3d radiation pattern ONLY

Select the plot display option: |
```

0- The key ‘0’ means the plot will happen without a graphic display. The data is saved to the CSV file and intended to be post-processed later. This can be useful for unattended large plots, because the 3D plot takes quite a bit of CPU resource which delays the plot.

1- The key ‘1’ means that during the plot, a graphic 3D plot will show, to initiate the plot we fill in the plot parameters which are the start H angle, the stop H angle, the start V angle, and the stop V angle, then the resolution step size. Finally, the menu asks for an optional label to the plot record file, in this example we wrote ‘real 2D surface’ as our tag.

```
Select the plot display option: 1

Enter your start angle in horizontal plane in degree: -45
Enter your last angle in horizontal plane in degree: 45
Enter your start angle in vertical plane in degree: -30
Enter your last angle in vertical plane in degree: 30
Enter your step size in degree : 10

Enter a tag to append to filename or [ENTER] for no tag: real 2D surface
```

Pressing enter, the motion warning is displayed, everything is ready, we can turn off the laser, close the door and make sure everything is ready.

☛ Note: there are checks for the plot parameters to be valid, for example if the start angle is greater than the stop angle, if the step size is bigger than the span, if the span is more than 360° etc. in this case you will be brought back to the menu.

Upon pressing the “space bar” on the keyboard the plot starts:

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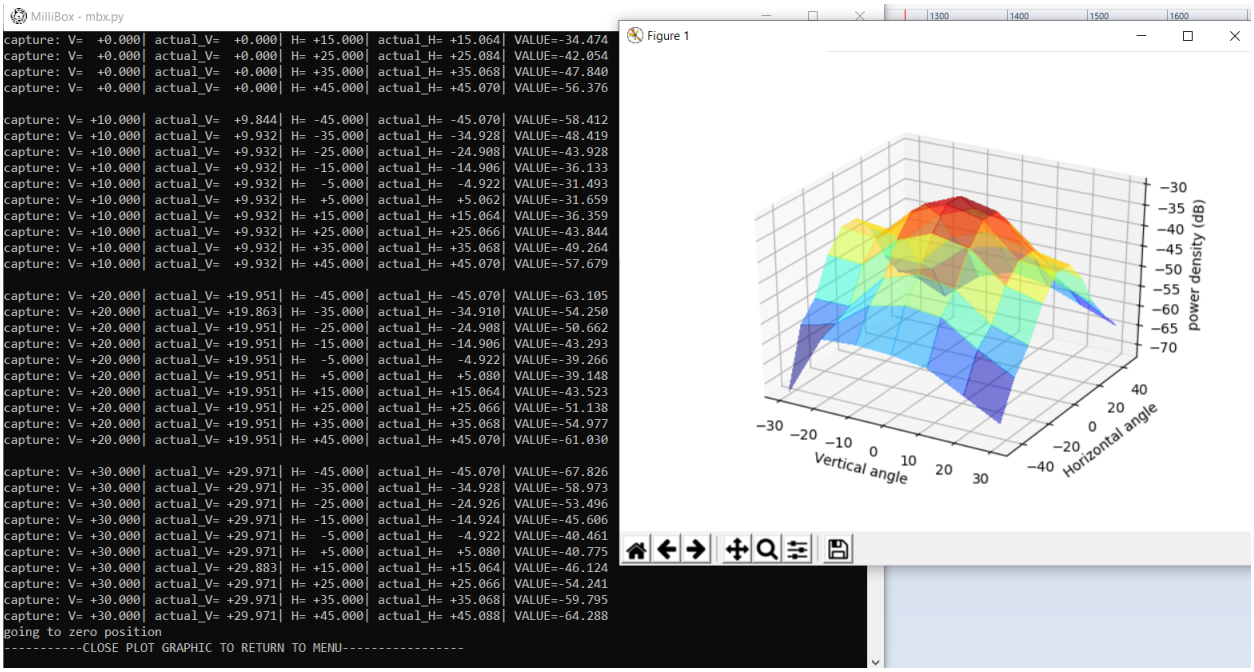
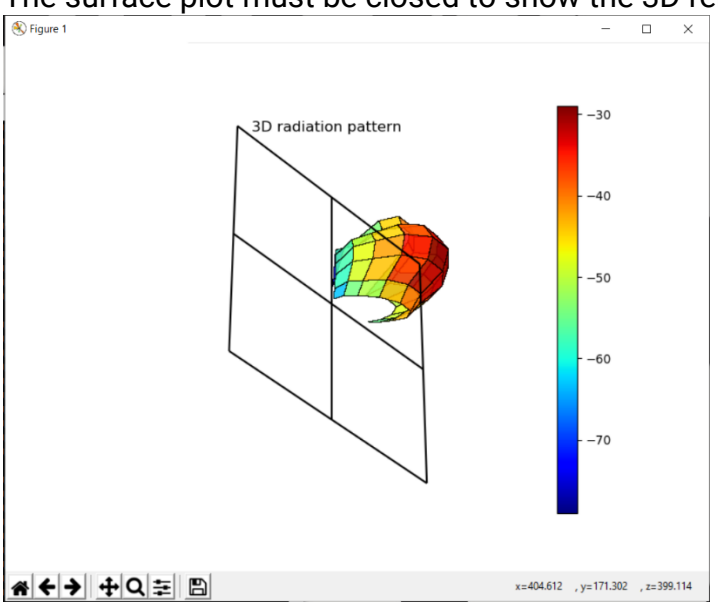


We see the plot log printing in the command window and the surface plot being displayed line by line as the plot progresses.
At the end, the 3D positioner goes back to its home position.
The surface plot must be closed to show the 3D rendered radiation pattern:



Then when the 3D radiation pattern is closed the command console goes back to the main menu.
We can now find the plot record we just created:
C:\SWMilliBox\MilliBox_plot_data\mbx_capture_2020-04-19-101322_2d_real 2D surface.csv
And see the data we collected on this plot:

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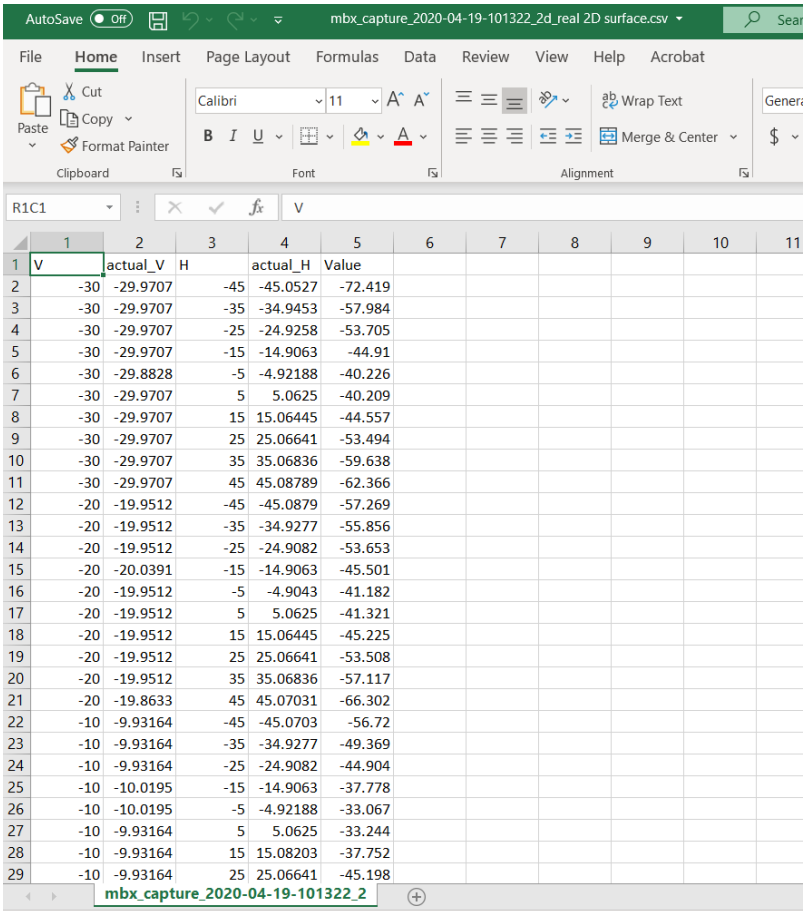

V	actual_V	H	actual_H	Value
-30	-29.9707	-45	-45.0527	-72.419
-30	-29.9707	-35	-34.9453	-57.984
-30	-29.9707	-25	-24.9258	-53.705
-30	-29.9707	-15	-14.9063	-44.91
-30	-29.8828	-5	-4.92188	-40.226
-30	-29.9707	5	5.0625	-40.209
-30	-29.9707	15	15.06445	-44.557
-30	-29.9707	25	25.06641	-53.494
-30	-29.9707	35	35.06836	-59.638
-30	-29.9707	45	45.08789	-62.366
-20	-19.9512	-45	-45.0879	-57.269
-20	-19.9512	-35	-34.9277	-55.856
-20	-19.9512	-25	-24.9082	-53.653
-20	-20.0391	-15	-14.9063	-45.501
-20	-19.9512	-5	-4.9043	-41.182
-20	-19.9512	5	5.0625	-41.321
-20	-19.9512	15	15.06445	-45.225
-20	-19.9512	25	25.06641	-53.508
-20	-19.9512	35	35.06836	-57.117
-20	-19.8633	45	45.07031	-66.302
-10	-9.93164	-45	-45.0703	-56.72
-10	-9.93164	-35	-34.9277	-49.369
-10	-9.93164	-25	-24.9082	-44.904
-10	-10.0195	-15	-14.9063	-37.778
-10	-10.0195	-5	-4.92188	-33.067
-10	-9.93164	5	5.0625	-33.244
-10	-9.93164	15	15.08203	-37.752
-10	-9.93164	25	25.06641	-45.198

2- the key '2' means that during the plot, a graphic heatmap will show, to initiate the plot we fill in the plot parameters which are the start H angle, the stop H angle, the start V angle, and the stop V angle, then the resolution step size. Finally, the menu asks for an optional label to the plot record file, in this example we wrote 'this is a heatmap plot' as our tag.

```
2
going to zero position
This is your zero position: center of the plot


************ 2-Axis Sweep ************

Plot display options:
  0 - no interactive plot display
  1 - 3d surface plot
  2 - 2d heatmap plot
  3 - multi-trace line plot
  4 - 3d radiation pattern ONLY

Select the plot display option: 2
```

Then we are asked to fill the plot properties:

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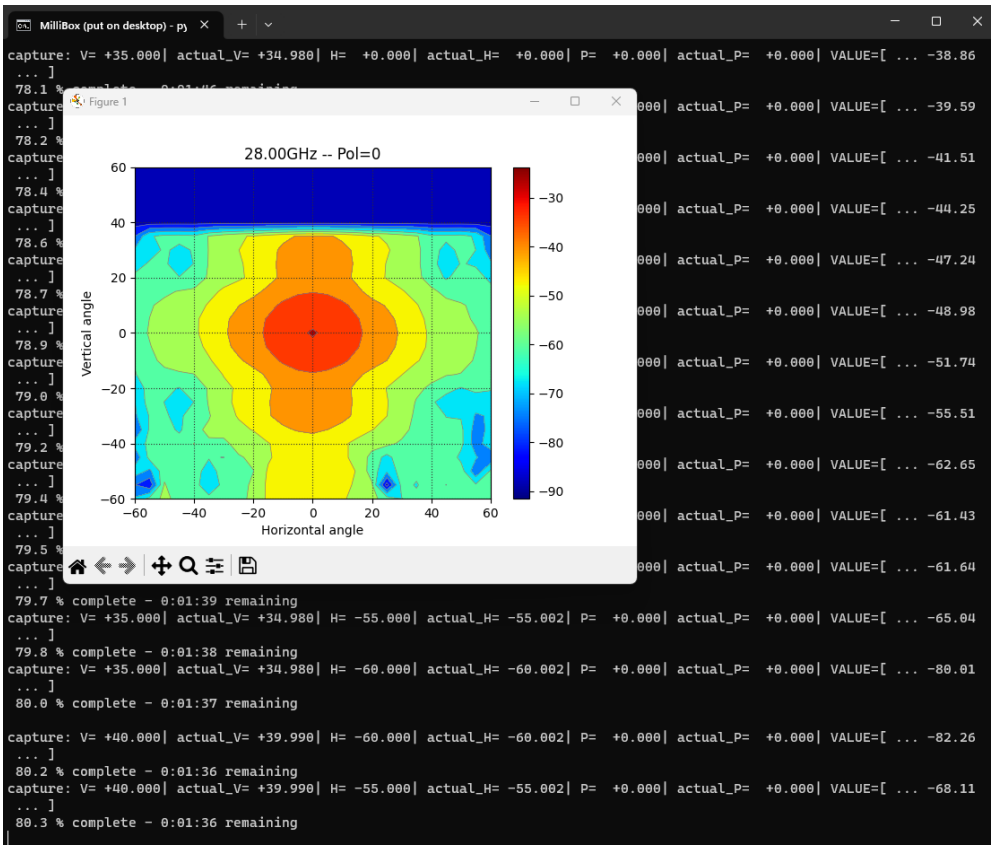
```
Select the plot display option: 2

Enter your start angle in horizontal plane in degree: -60
Enter your last angle in horizontal plane in degree: 60
Enter your start angle in vertical plane in degree: -60
Enter your last angle in vertical plane in degree: 60
Enter your step size in degree : 5
Enter your polarization position in degree : 0

Enter a tag to append to filename or [ENTER] for no tag: this is a heatmap plot
```

As the sweep progresses, you can see the heatmap display being filled up:



Then the plot is finished, and we are asked to close the plot to display the 3D rendering:

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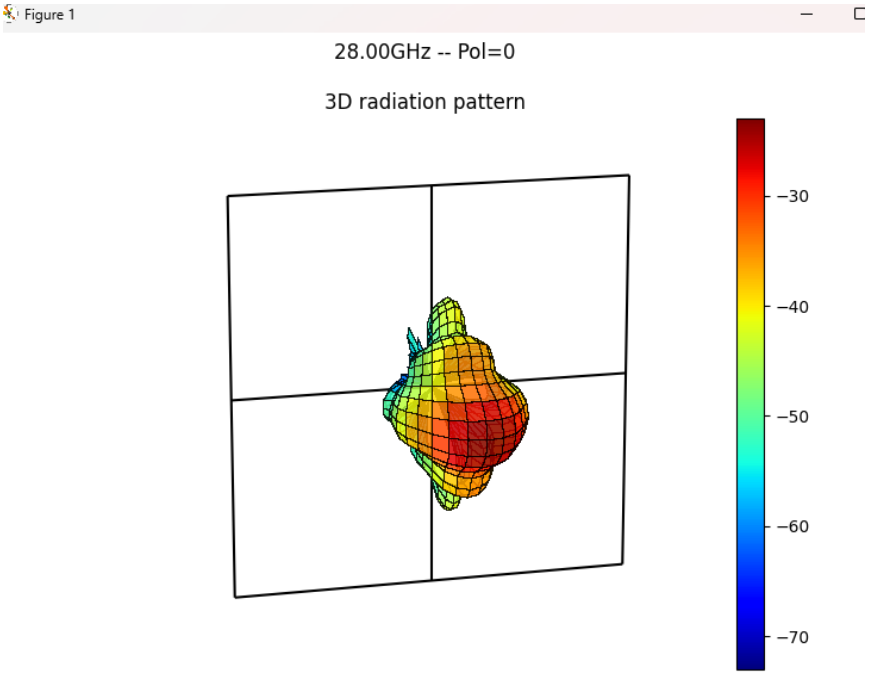

When we close it, we go back to the main menu.
We can check that a new plot record file has been created in:
C:\SWMilliBox\MilliBox_plot_data \ mbx_capture_2023-10-13-093024_2d_this is a heatmap plot.csv

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	A	B	C	D	E	F	G	H
1	V	actual_V	H	actual_H	P	actual_P	28000000000	
2	-60	-60.0293	-60	-60.0021	0	0	-70.96	
3	-60	-60.0293	-55	-55.0021	0	0	-61.37	
4	-60	-60.0293	-50	-50.0018	0	0	-53.65	
5	-60	-60.0293	-45	-45.0015	0	0	-59.07	
6	-60	-60.0293	-40	-40.0012	0	0	-56.44	
7	-60	-60.0293	-35	-35.0012	0	0	-60.98	
8	-60	-60.0293	-30	-30.0009	0	0	-60.1	
9	-60	-60.0293	-25	-25.0009	0	0	-61.78	
10	-60	-60.0293	-20	-20.0006	0	0	-51.33	
11	-60	-60.0293	-15	-15.0006	0	0	-47.11	
12	-60	-60.0293	-10	-10	0	0	-45.45	
13	-60	-60.0293	-5	-5	0	0	-44.1	
14	-60	-60.1172	0	0	0	0	-43.21	
15	-60	-60.0293	5	5.0002962	0	0	-44.64	
16	-60	-60.0293	10	10.000592	0	0	-47.27	
17	-60	-60.0293	15	15.000592	0	0	-49.95	
18	-60	-60.0293	20	20.000592	0	0	-54	
19	-60	-60.0293	25	25.000888	0	0	-59.11	
20	-60	-60.0293	30	30.001185	0	0	-64.23	
21	-60	-60.0293	35	35.001185	0	0	-62	
22	-60	-60.0293	40	40.001481	0	0	-60.94	
23	-60	-60.0293	45	45.001481	0	0	-57.33	
24	-60	-60.0293	50	50.001481	0	0	-57.22	
25	-60	-60.0293	55	55.001777	0	0	-62.74	
26	-60	-60.0293	60	60.002074	0	0	-63.46	
27	-55	-55.0195	-60	-60.0021	0	0	-79.78	
28	-55	-55.0195	-55	-55.0018	0	0	-86.51	
29	-55	-55.0195	-50	-50.0018	0	0	-55.2	
30	-55	-55.0195	-45	-45.0015	0	0	-63.49	
31	-55	-55.0195	-40	-40.0015	0	0	-59.76	
32	-55	-55.0195	-35	-35.0012	0	0	-71.91	

3- the key '3' means that during the plot, a flat multiline plot will show, to initiate the plot we fill in the plot parameters which are the start H angle, the stop H angle, the start V

```
************ 2-Axis Sweep ************

Plot display options:
  0 - no interactive plot display
  1 - 3d surface plot
  2 - 2d heatmap plot
  3 - multi-trace line plot
  4 - 3d radiation pattern ONLY

Select the plot display option: 3

Enter your start angle in horizontal plane in degree: -90
Enter your last angle in horizontal plane in degree: 90
Enter your start angle in vertical plane in degree: -90
Enter your last angle in vertical plane in degree: 90
Enter your step size in degree : 5
Enter your polarization position in degree : 0

Enter a tag to append to filename or [ENTER] for no tag: this is real 3D line plot
```


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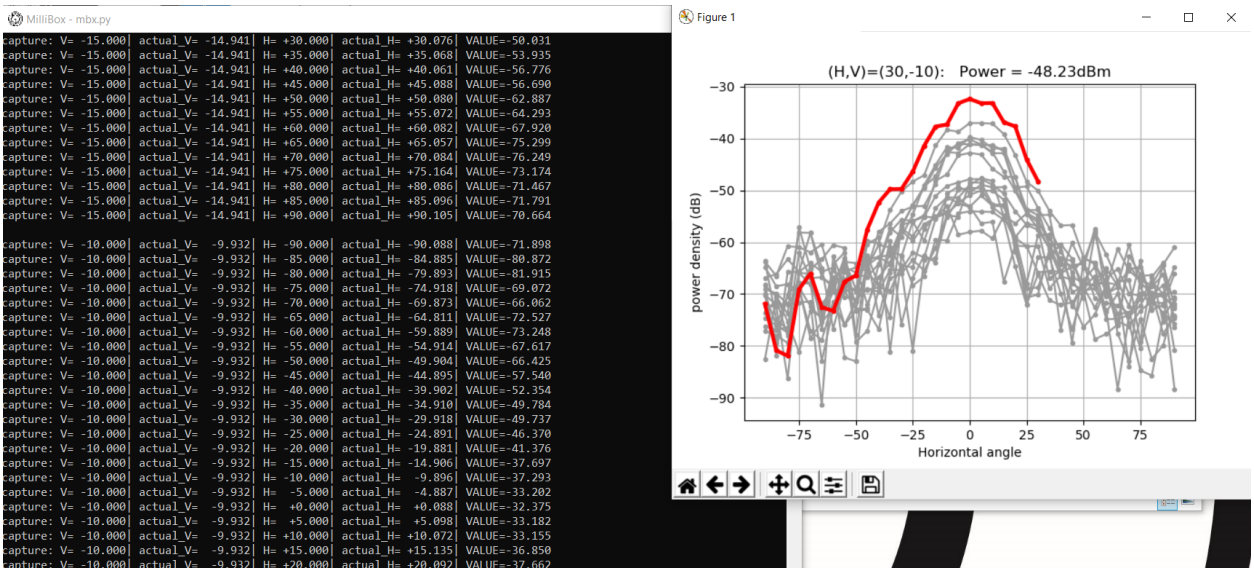
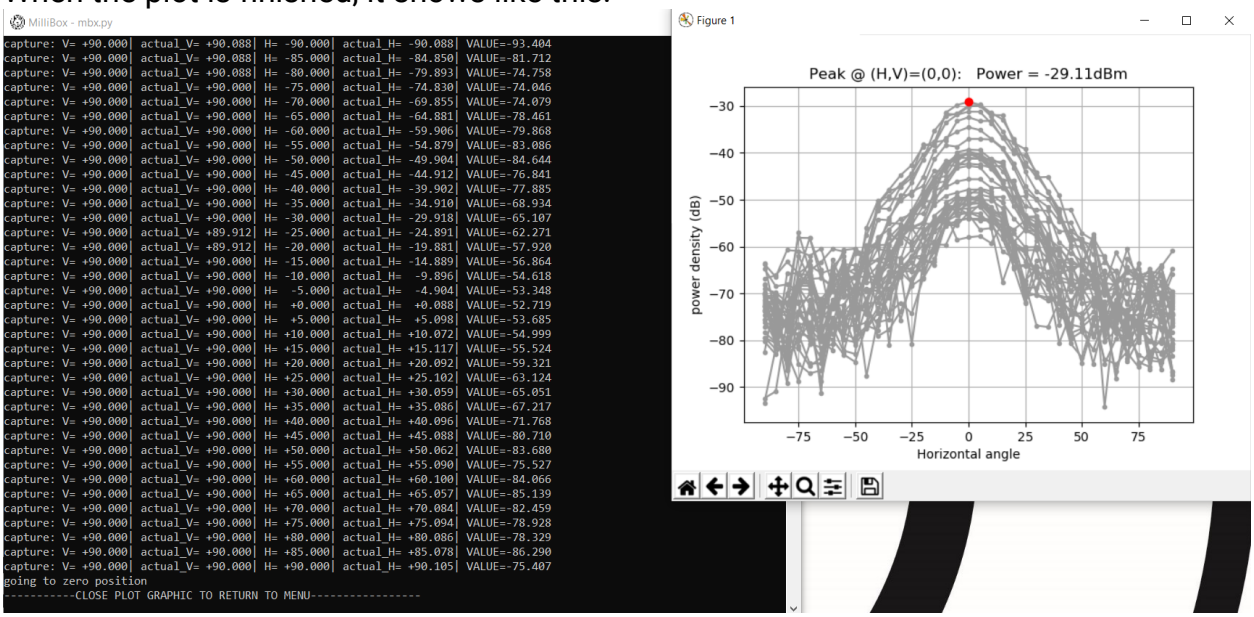
As the plot progresses, each radiation slice is displayed as a new line superimposed on the previous line:



When the plot is finished, it shows like this:



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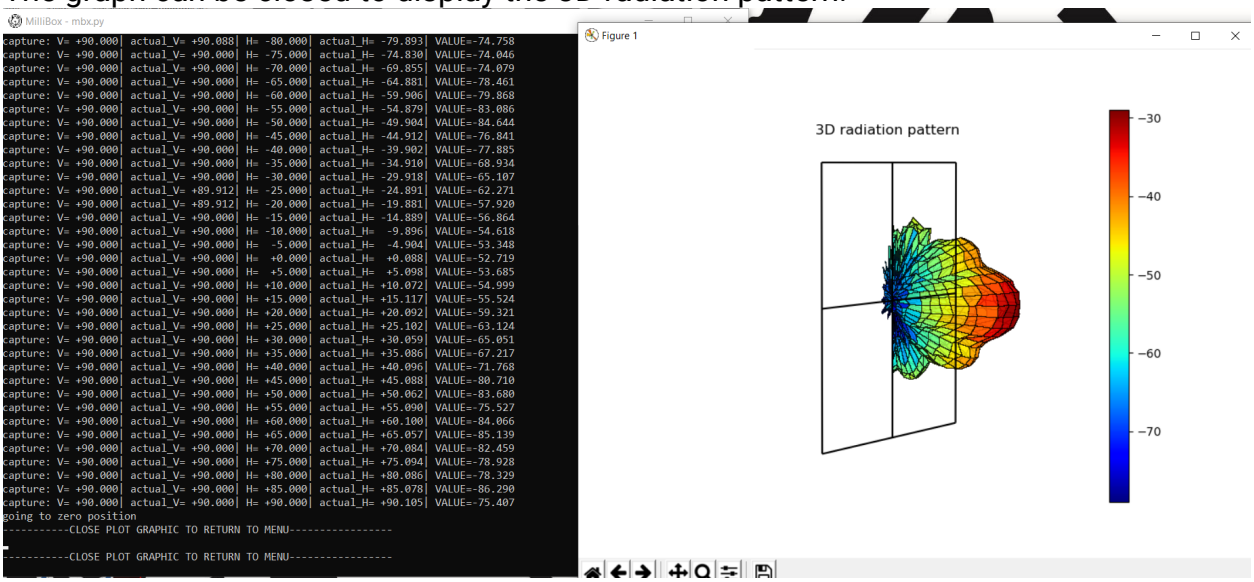
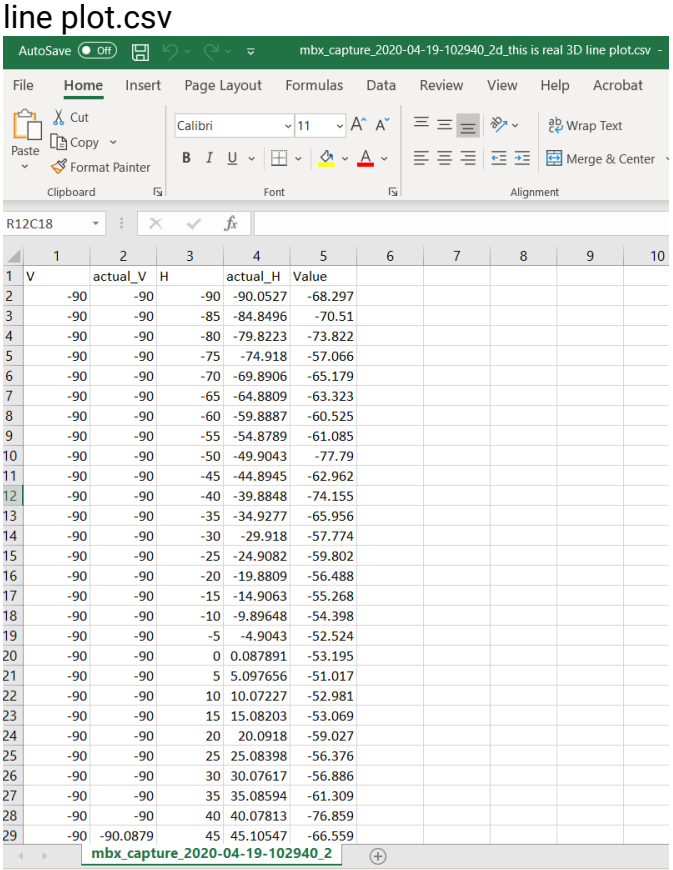
The graph can be closed to display the 3D radiation pattern:



When the 3D radiation pattern rendering is closed, the console goes back to the main menu.

We can check that a new plot record file has been created in: C:\SWMilliBox\MilliBox_plot_data \mbx_capture_2020-04-19-102940_2d_this is real 3D line plot.csv



V	actual_V	H	actual_H	Value
-90	-90	-90	-90.0527	-68.297
-90	-90	-85	-84.8496	-70.51
-90	-90	-80	-79.8223	-73.822
-90	-90	-75	-74.918	-57.066
-90	-90	-70	-69.8906	-65.179
-90	-90	-65	-64.8809	-63.323
-90	-90	-60	-59.8887	-60.525
-90	-90	-55	-54.8789	-61.085
-90	-90	-50	-49.9043	-77.79
-90	-90	-45	-44.8945	-62.962
-90	-90	-40	-39.8848	-74.155
-90	-90	-35	-34.9277	-65.956
-90	-90	-30	-29.918	-57.774
-90	-90	-25	-24.9082	-59.802
-90	-90	-20	-19.8809	-56.488
-90	-90	-15	-14.9063	-55.268
-90	-90	-10	-9.89648	-54.398
-90	-90	-5	-4.9043	-52.524
-90	-90	0	0.087891	-53.195
-90	-90	5	5.097656	-51.017
-90	-90	10	10.07227	-52.981
-90	-90	15	15.08203	-53.069
-90	-90	20	20.0918	-59.027
-90	-90	25	25.08398	-56.376
-90	-90	30	30.07617	-56.886
-90	-90	35	35.08594	-61.309
-90	-90	40	40.07813	-76.859
-90	-90.0879	45	45.10547	-66.559

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4- pressing the key '4' means that during the plot, only the log will appear during the plot and at the end of the plot the 3D radiation pattern will be displayed:

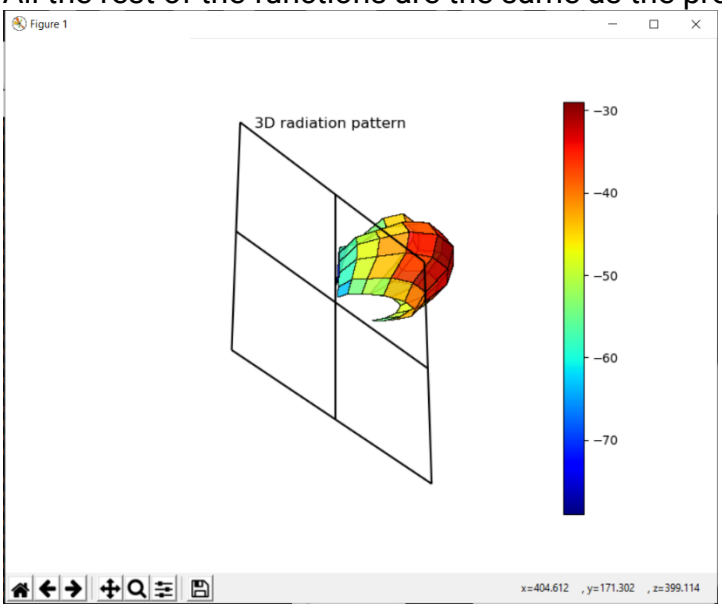
```
2
going to zero position
This is your zero position: center of the plot


************ 2-Axis Sweep ************

Plot display options:
  0 - no interactive plot display
  1 - 3d surface plot
  2 - 2d heatmap plot
  3 - multi-trace line plot
  4 - 3d radiation pattern ONLY

Select the plot display option: 4
```

All the rest of the functions are the same as the previous plots:



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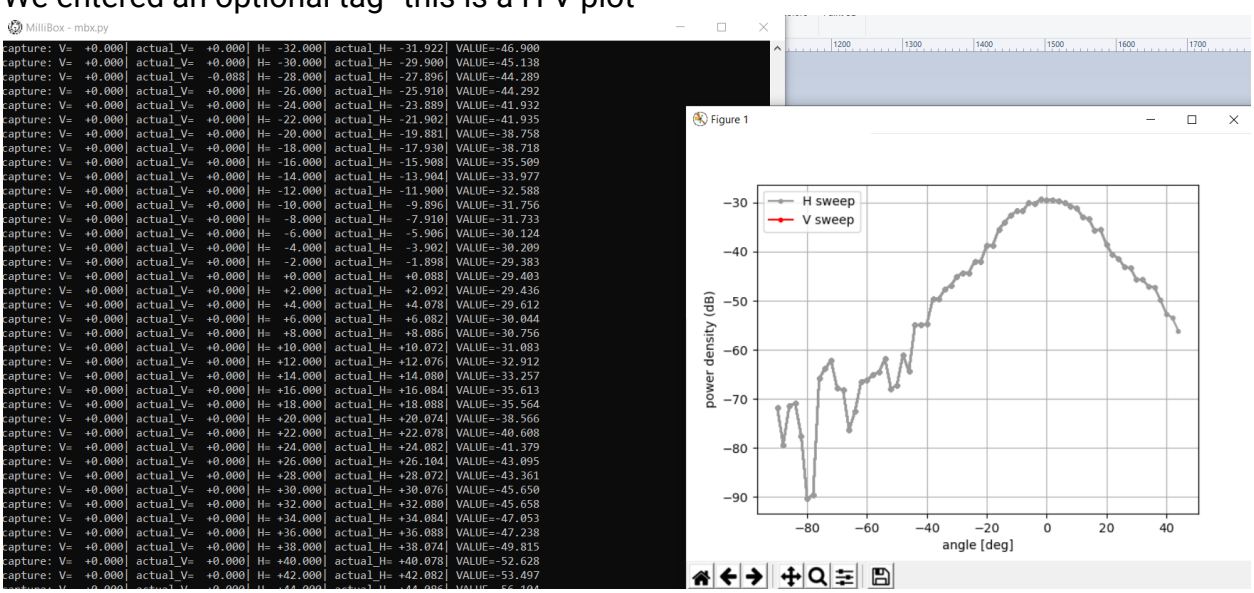
press <3> to start a 1-D sweep in E-plane and H-plane

The “3” key is used to execute a H, V plot. The H,V plot consists of a slice in horizontal plane and a slice in vertical plane displayed on one plot.
The submenu appears:

```
************ 1-D Single Direction Sweep in E-plane and H-plane ************

Plot display options:
  0 - no interactive plot
  1 - interactive plot

Select the plot display option: 1

Enter your start angle in degree: -90
Enter your last angle in degree: 90
Enter your step size in degree : 2

Enter a tag to append to filename or [ENTER] for no tag: this is a H V plot
```

In this menu the start and stop angle are the same in H and V plane.
We entered an optional tag “this is a H V plot”



As the plot progresses it displays the plot in a flat graphic and shows the log in the console

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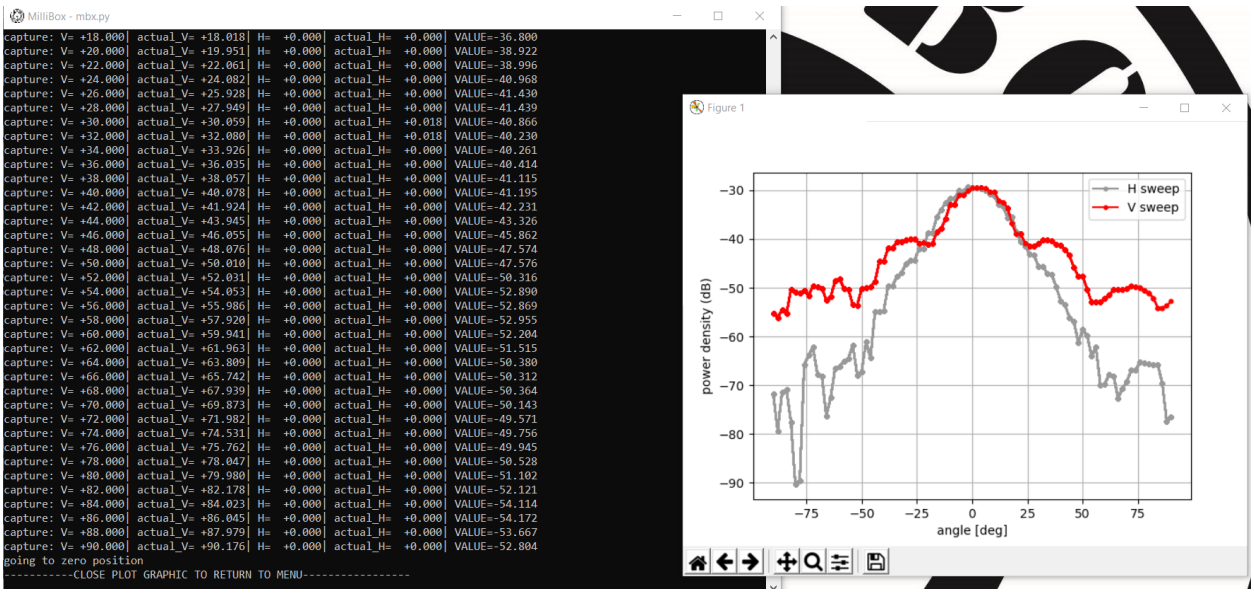
When finished it looks like below:



When the plot is closed the main menu appears.
As for any other plots the recorded .csv file be retrieved from the capture directory
`C:\SWMilliBox\MilliBox_plot_data`

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DATA POST-PROCESSING section:

press <p> to plot from previous measurement

The “p” key is for plot playback, it allows you to redraw any `*.csv` file from a sweep made previously and stored in `C:\SWMilliBox\MilliBox_plot_data\` and sub-directories.
This menu also allows you to 3D print 3D radiation patterns.
Upon pressing the ‘p’ key on the keyboard, the following menu appears:

```
p

************* PLOTTING MAIN MENU *********************
**************** USE KEYBOARD ************************
* Press <ESC> or <q> to quit plot menu
* press <a> for 1D sweep - Line Plot
* press <b> for HV sweep - Line Plot
* press <c> for 2D sweep - Surface Plot (HV) / Direction Cosine Plot (SPH)
* press <d> for 2D sweep - Heatmap Plot (HV) / Polar Plot (SPH)
* press <e> for 2D sweep - Multi-Line Slice Plot (HV)
* press <f> for 2D sweep - 3D Radiation Pattern Plot (HV/SPH)
*****************************************************
```

There are 6 types of plots:

- with “a” key select a 1D sweep, which is a single line plot.
- With “b” key select a HV sweep, which is a 2 orthogonal line plot.
- With “c” key select a 2D sweep, which for all HV positioners is a Surface Plot and for Spherical Roll positioner is a Direction Cosine Plot.
- With “d” key select a 2D sweep, which for all HV positioners is a Heatmap Plot and for Spherical Roll positioner is a Polat Plot.
- With “e” key select a 2D sweep, which for all HV positioners is Multi-Line Slice Plot
- With “f” key select a 2D sweep, which is for all positioner is a 3D Radiation Pattern Plot.

Here is an illustration of the different plots for HV positioner (GIM01, GIM03, GIM04, GIM06)

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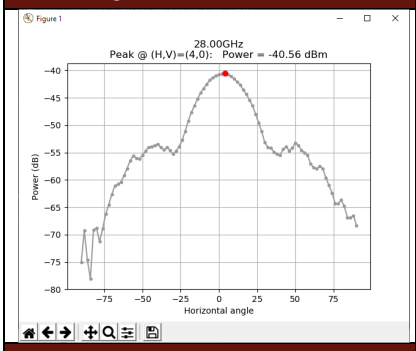
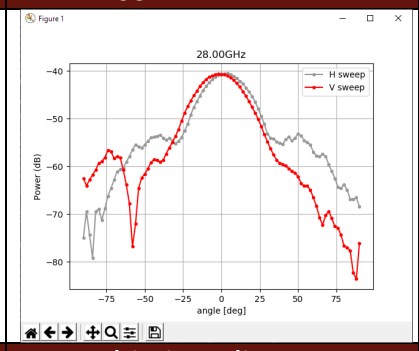
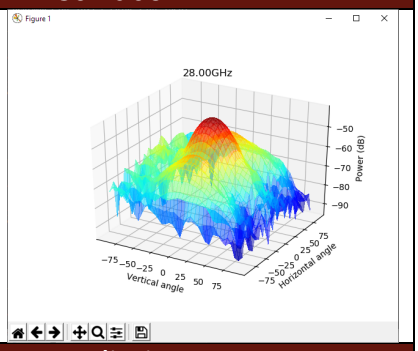
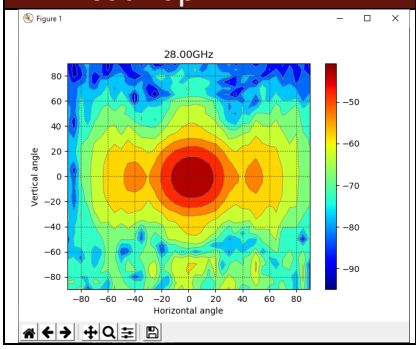
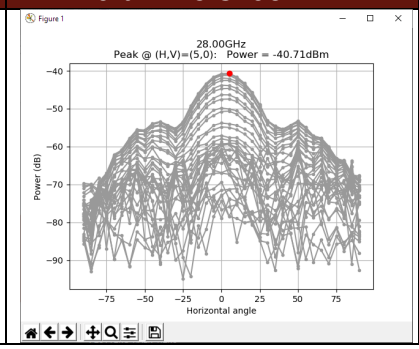
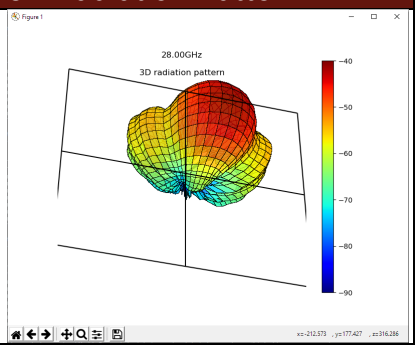
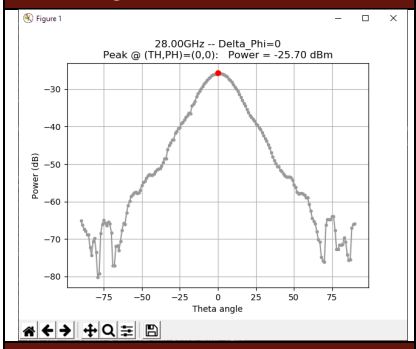
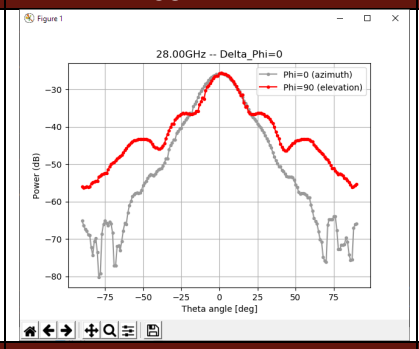
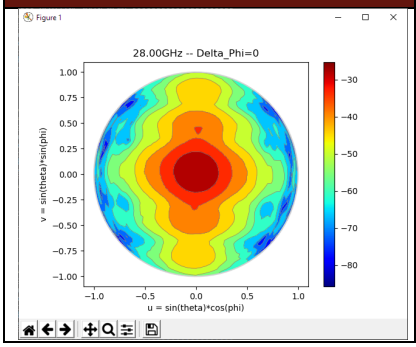
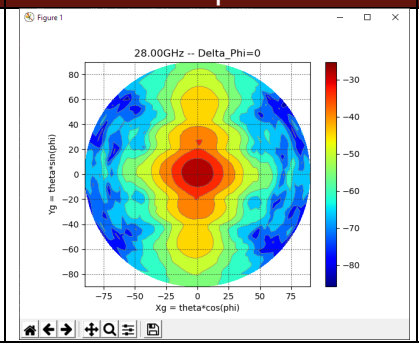
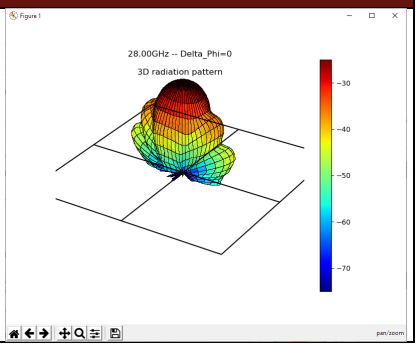
1D Line	HV Lines	2D Surface
		
2D Heatmap	**2D Multi-Line Slice**	**3D Radiation Pattern**
		

Here is an illustration of the different plots for Spherical Roll positioner (GIM05)

1D Line	Az- El Lines	
		
Direction Cosine	**Polar Heatmap**	**3D Radiation Pattern**
		

For these plots to be displayed, the data in the file must be captured and formatted consistently with the plot that was selected. If there is a mismatch, an error message will be displayed, and no plot will be generated.

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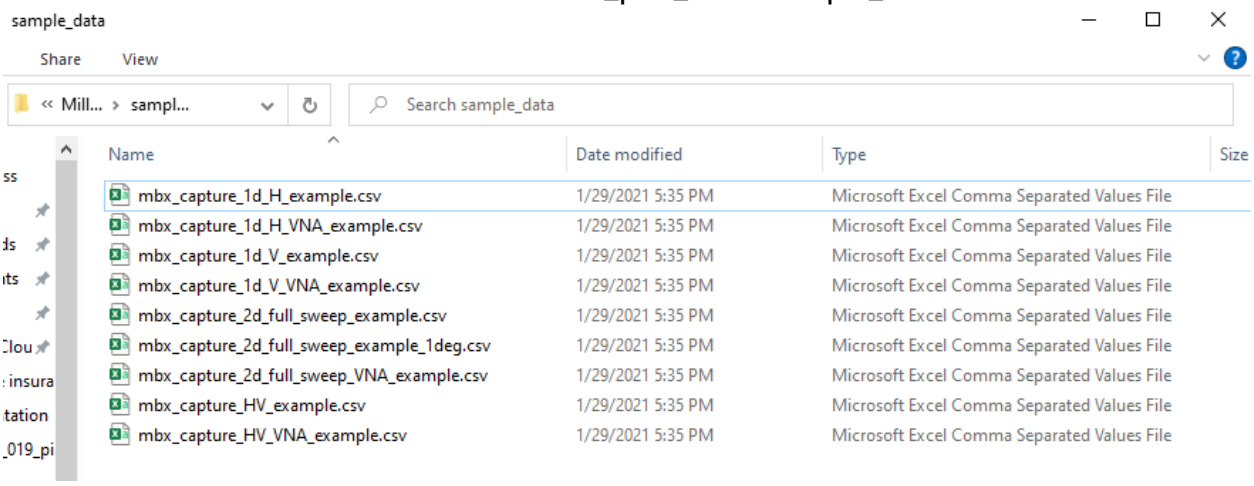
Each type of sweep has example `*.csv` files available for testing,
Those are found in C:\SWMilliBox\MilliBox_plot_data\sample_data\



For instance, we want to playback: mbx_capture_2d_full_sweep_example_1deg.csv
In the console menu we press “f” because it is a 2D sweep and we want to display it in 3D Radiation Pattern Plot, this appears:

```
************* PLOTTING MAIN MENU *********************
**************** USE KEYBOARD ************************
* Press <ESC> or <q> to quit plot menu
* press <a> for 1D sweep - Line Plot
* press <b> for HV sweep - Line Plot
* press <c> for 2D sweep - Surface Plot (HV) / Direction Cosine Plot (SPH)
* press <d> for 2D sweep - Heatmap Plot (HV) / Polar Plot (SPH)
* press <e> for 2D sweep - Multi-Line Slice Plot (HV)
* press <f> for 2D sweep - 3D Radiation Pattern Plot (HV/SPH)
*****************************************************
f
```

We copy the file name like this:

```
************* PLOTTING MAIN MENU *********************
**************** USE KEYBOARD ************************
* Press <ESC> or <q> to quit plot menu
* press <a> for 1D sweep - Line Plot
* press <b> for HV sweep - Line Plot
* press <c> for 2D sweep - Surface Plot (HV) / Direction Cosine Plot (SPH)
* press <d> for 2D sweep - Heatmap Plot (HV) / Polar Plot (SPH)
* press <e> for 2D sweep - Multi-Line Slice Plot (HV)
* press <f> for 2D sweep - 3D Radiation Pattern Plot (HV/SPH)
*****************************************************
f

Filename to plot or [ENTER] to cancel: mbx_capture_2d_full_sweep_example_1deg.csv
```

Then, when pressing enter the plot is rendered as expected:

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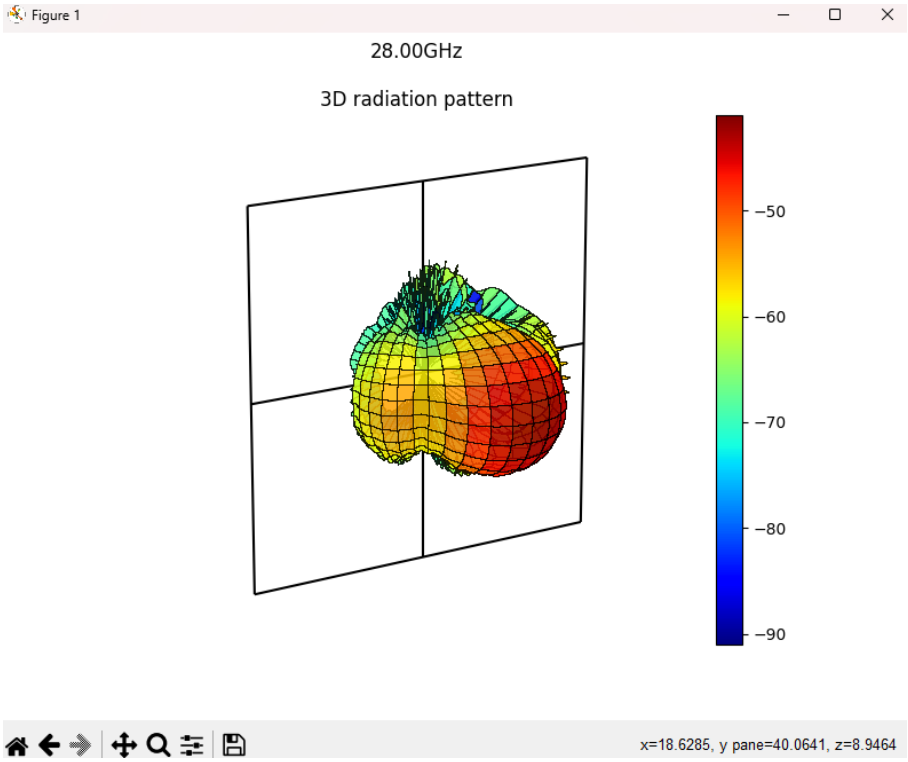

When we close the display window we are prompted to decide if we want to convert this plot to a printable file in .STL format:

```
Filename to plot or [ENTER] to cancel: mbx_capture_2d_full_sweep_example_1deg.csv

Plotting file: ..\..\MilliBox_plot_data\sample_data\mbx_capture_2d_full_sweep_example_1deg.csv
-----------CLOSE PLOT GRAPHIC TO RETURN TO MENU----------------

Save STL file for 3D printing? [Y/N]
```

If we press “Y” we are brought to the 3D print STL generation Menu

```
Save STL file for 3D printing? [Y/N]
Enter dB dynamic range for STL file (ENTER for default=40): 40
Enter maximum radial dimension in mm (ENTER for default=200): 200
Enter minimum radial dimension in mm (ENTER for default=25): 25
Wrote 65520 facets
Saved STL to file: ..\..\MilliBox_plot_data\stl\radpat_mbx_capture_2d_full_sweep_example_1deg_f28000.stl
```

Here we are just inputting the default values, we could have just hit ENTER instead.
The STL generation worked, and a file is created at:
“C:\SWMilliBox\MilliBox_plot_data\stl\radpat_mbx_capture_2d_full_sweep_example_1deg_f28000.stl”

With our 3D printer tool we can open this file and inspect it

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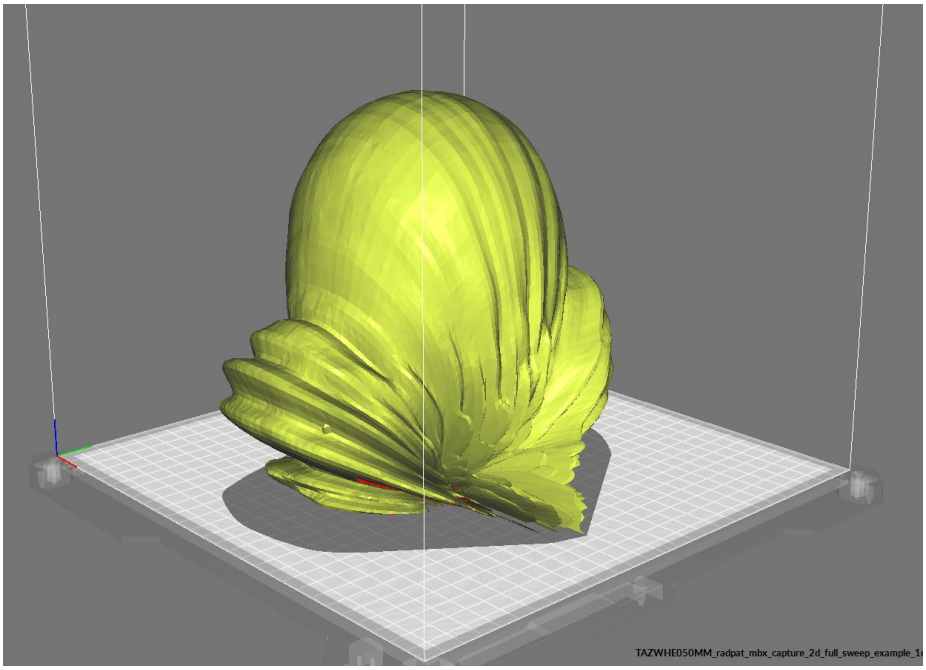
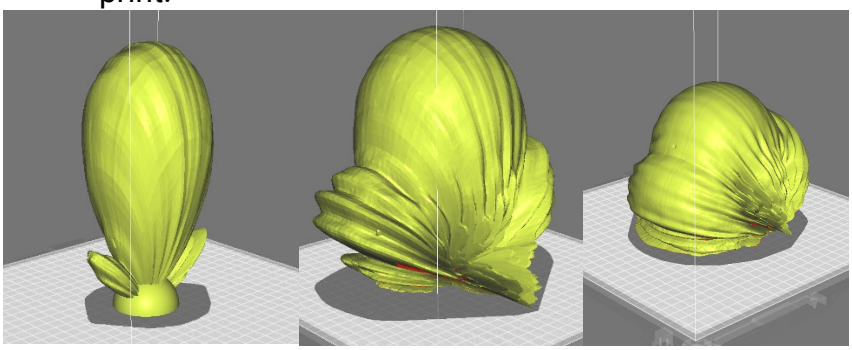


As for non-default parameters:

- dB dynamic range for STL file has a significant impact on the outcome of the print.



Dynamic Range 20dB Dynamic Range 40dB Dynamic Range 80dB

Those 3 STL files are from the same exact radiation pattern, where only the dynamic range has changed. 40 dB is the default value and usually the most visually appealing. But there is no right or wrong, it just depends on your preferences.

- Maximum radial dimension and Minimum radial dimension gives a dimension to the 3D print. Our default is 200mm and 25mm, but other values can be selected. There will be warnings and errors if the parameters can't be processed.

☛ Note: The minimum radial dimension (default 25mm) superimposes a sphere or hemisphere onto the radiation pattern. This helps avoid sharp discontinuities near the origin and introduces a 50mm diameter base at the bottom of the radiation pattern that provides the print some support and improve printability.

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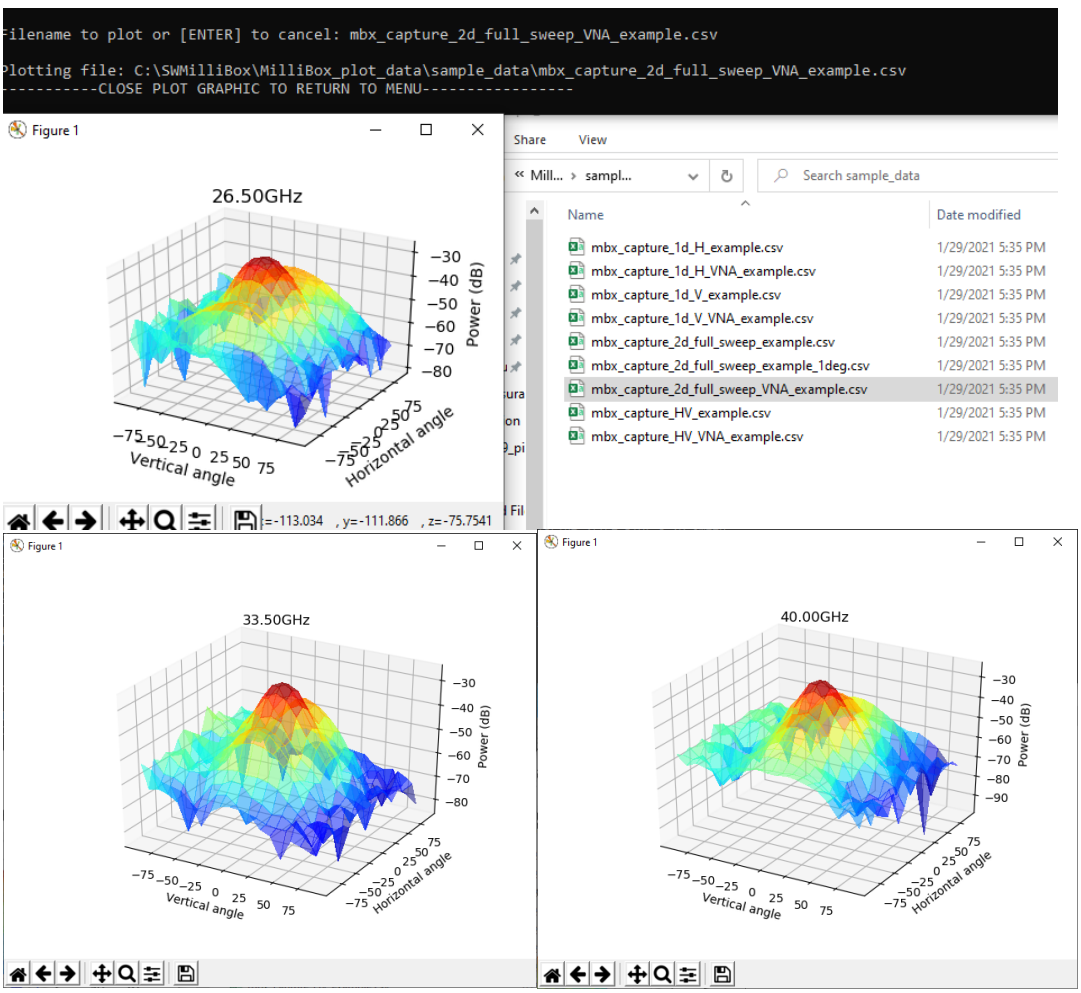
Note: We do not guarantee that the STL file can be converted to GCODE for specific printers. We have tested with Cura for Ultimaker and Lulzbot successfully, but there are so many versions out there that some printer software may not work.

For VNA based sweep, since multiple frequencies are captured at the same time during the sweep, the prompt ask us to either display the minimum frequency plot, the middle frequency plot and the maximum frequency plot or to choose a particular frequency to display.

```
c

Filename to plot or [ENTER] to cancel: mbx_capture_2d_full_sweep_VNA_example.csv

Plotting file: ..\..\MilliBox_plot_data\sample_data\mbx_capture_2d_full_sweep_VNA_example.csv

*** VNA DATA FILE DETECTED ***

Enter the freq [GHz] to plot (or enter 0 to plot min/mid/max): 0
```

For default we select “0”



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press </> to display post-processing menu

The "/" key is used to display the post processing menu

```
************** POST-PROCESSING MAIN MENU **************
******************** USE KEYBOARD *********************
* Press <ESC> or <q> to quit post-process menu
* press <a> to calculate difference of two measurements
* press <b> to calculate total power from orthogonal measurements
*******************************************************
```

Press "a" to calculate the difference between 2 plots.
This is particularly useful when debugging or comparing antenna designs.

In this example we have captured 2 plots that should be the same. One is our baseline and is called `mbx_capture_2024-09-01-103650_2d_baseline.csv` the other is a deteriorated capture called `mbx_capture_2024-09-01-145713_2d_deteriorate.csv`. When we captured `mbx_capture_2024-09-01-145713_2d_deteriorate.csv` we inserted a block in the chamber during the measurement.

We can create a directory which we call `diff_plot` and we store there those 2 csv files.

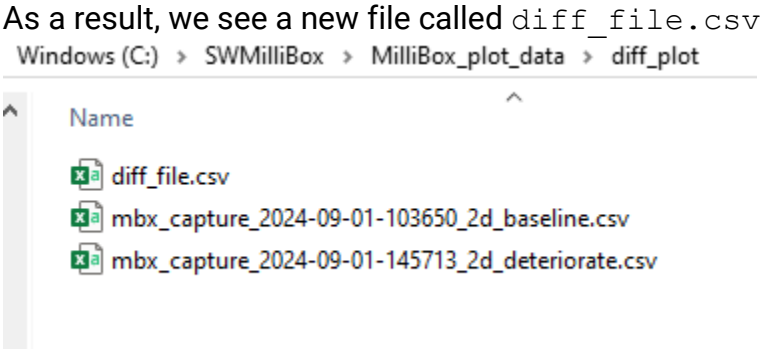
Then we follow the menu, and this creates a new file which we call `diff_file.csv`

```
************** POST-PROCESSING MAIN MENU **************
******************** USE KEYBOARD *********************
* Press <ESC> or <q> to quit post-process menu
* press <a> to calculate difference of two measurements
* press <b> to calculate total power from orthogonal measurements
*******************************************************
a

Run directory or [ENTER] to cancel: C:\SWMilliBox\MilliBox_plot_data\diff_plot
First file to load or [ENTER] to cancel: mbx_capture_2024-09-01-103650_2d_baseline.csv
Second file to load or [ENTER] to cancel: mbx_capture_2024-09-01-143254_2d_deteriorate.csv
Output file to save or [ENTER] to cancel: diff_file.csv

*** SAVED! - C:\SWMilliBox\MilliBox_plot_data\diff_plot\diff_file.csv
```

As a result, we see a new file called `diff_file.csv` in our `diff_plot` directory.



We can now go back to the main menu and plot the diff_file.csv to look at it

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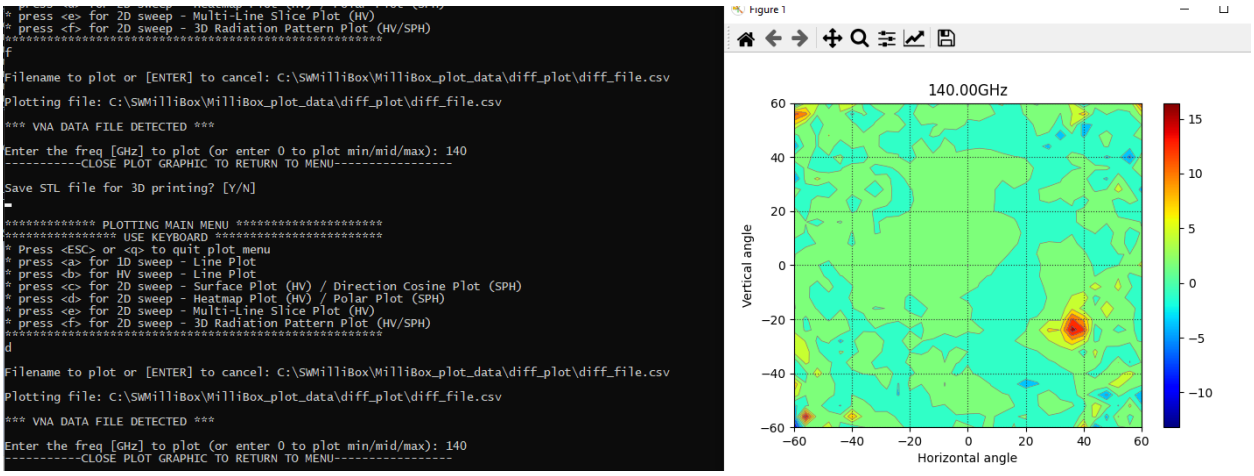
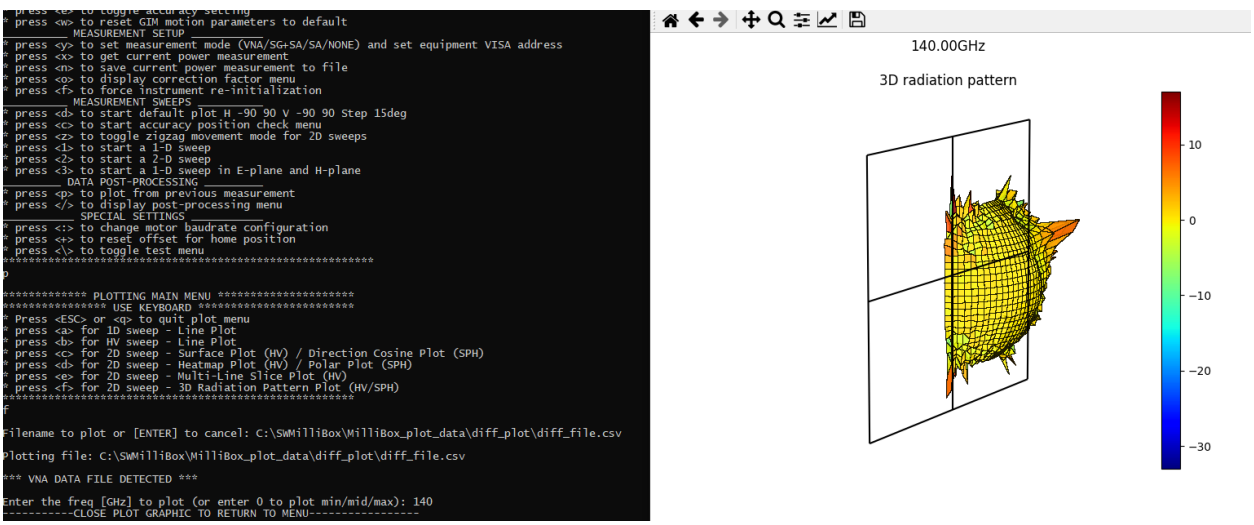


We can clearly see a red spot which corresponds to the place where the blocker was impacting the radiation pattern.

We can also observe it in 3D, and we see a spike of high differences in the data from baseline capture and the data from the deteriorated capture which match the orientation of the blocker that we placed.



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Or else we can press “b” to calculate the total power from orthogonal measurement. This is useful for a case where the antenna does not have a clear polarization, for example a patch and we would like to sum the power of two orthogonal polarization captures to get a sense of our total radiated power. This method kind of gives the capability of a dual polarized horn and 4 port VNA, when we in fact have only a single polarized horn and a 2 port VNA.

Here we have created a directory called “`Ortho_plots`” in “`C:\SWMilliBox\MilliBox_plot_data`” which we have 2 plots of the same DUT captured in H Polarization and V Polarization. Then we decide to create a HV combination called: “`combined_mbx_capture_2023-10-13.csv`”

```
Run directory or [ENTER] to cancel: C:\SWMilliBox\MilliBox_plot_data\Ortho_plots
First file to load or [ENTER] to cancel: mbx_capture_2023-10-13-114217_2d_HPol.csv
Second file to load or [ENTER] to cancel: mbx_capture_2023-10-13-115906_2d_VPol.csv
Output file to save or [ENTER] to cancel: combined_mbx_capture_2023-10-13.csv
```

We use “p” to display the resulting file in 3D:

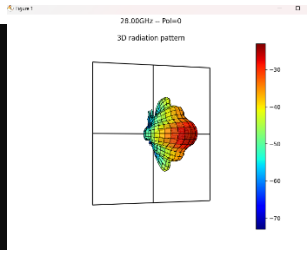
```
f

Filename to plot or [ENTER] to cancel: combined_mbx_capture_2023-10-13.csv

Plotting file: ..\..\MilliBox_plot_data\combined_mbx_capture_2023-10-13.csv

*** VNA DATA FILE DETECTED ***

Enter the freq [GHz] to plot (or enter 0 to plot min/mid/max): 28
```



We now have a dataset which sums the power from two orthogonally polarized capture files.

Then Press “b” to calculate the difference between 2 plots.
This is particularly useful when debugging or comparing antenna designs.

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SPECIAL SETTINGS section:

press <:> to change motor baudrate configuration

The ":" key is used to change the Motor baud rate setting. By default, the motor and the `mbx.py` configuration are set to 1Mbps. However, the MacOS driver is limited and 57600kbps baud rate is used instead. So, to configure a 3D positioner for MacOS, the ":" key is used on a Windows system to reconfigure the 3D positioner to 57600kpbs baudrate, then the 3D positioner will operate normally with a MacOS system.

press <+> to reset offset for home position

The "+" key is used to reset the offset parameters. The offset parameters are the ones recording the 3D positioner 0,0 position in the motor flash. There could be instances where the 0,0 position has drifted through successive realignments in the same direction. The offset parameters are limited to +/-255 revolutions in V and +/-51 revolutions in H. If the 3D positioner has reached this limit, the offset can no longer be aligned. In this instance the w key can be used to reset the offset to zero.
For this operation try to move the 3D positioner as close as possible to the desired 0,0, then press 'w' key.

☛ Note: the drift in offset position only occurs when the motor is unpowered while the 3D positioner is not in 0.0 position. So, a good practice is always to go back to home position after a plot or at least before power down, and to never move the positioner manually while powered off. This is because the motor absolute encoder is 360° but in H plane the 3D positioner has a 5:1 gear ratio. Motor H only knows its absolute position modulo 360/5 i.e. 72°. This means that if the motor H is within +/- 36°of its 0.0 position upon power down and power up, the offset will not drift.

press <\> to toggle test menu

The "\" key is used to enable/disable and display/don't display additional test menu items which are mainly useful for demonstrating or testing a setup.

```
**********************  TEST MENU  **********************
* press <!> to show Gimbal platform
* press <@> to test Gimbal full range of motion
* press <#> to run a full Gimbal sweep H -180 180 V -180 180 Step 20deg
* press <$> to run Gimbal autonomous move
* press <%> to run Gimbal sweep H -40 40 V -40 40 Step 5deg - 2D heatmap plot
*******************************************************
```


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Key “!” turns the positioner to -110°, 0°, 0° which allows the positioner platform to be visible from the chamber door.

Key “@” makes all axis move to min position limit then to max position limit in sequence. This shows the positioner movement capabilities, and it can be used to test if the motion happens unobstructed.

Key “#” starts a preformatted sweep of -180° +180° at 20° step.

Key “$” sets the positioner in a synchronized move on all axis continuously, pressing the Space bar to start and the “esc” key to stop. This is mainly used for demos.

Key “%” starts a preformatted sweep of H -40° 40° V -40° 40° Step 5° in 2D heatmap plot mode. This is mainly used for demos.

The test menu also adds additional options to the plotting menu accessed using “p”. These options allow you to see how the different plots look using sample data

```
************* PLOTTING MAIN MENU ********************
**************** USE KEYBOARD ************************
* Press <ESC> or <q> to quit plot menu
* press <a> for 1D sweep - Line Plot
* press <b> for HV sweep - Line Plot
* press <c> for 2D sweep - Surface Plot (HV) / Direction Cosine Plot (SPH)
* press <d> for 2D sweep - Heatmap Plot (HV) / Polar Plot (SPH)
* press <e> for 2D sweep - Multi-Line Slice Plot (HV)
* press <f> for 2D sweep - 3D Radiation Pattern Plot (HV/SPH)
*********************************************************
**********************  TEST MENU  **********************
* press <!> for 1D line plot of sample 1D sweep
* press <@> for HV line plot of sample HV sweep
* press <#> for surface plot of sample 2D sweep
* press <$> for heatmap plot of sample 2D sweep
* press <%> for multi-line slice plot of sample 2D sweep
* press <^> for 3D radiation pattern plot of sample 2D sweep
*************************************************************
* press <1> for 1D line plot of sample 1D sweep (VNA)
* press <2> for HV line plot of sample HV sweep (VNA)
* press <3> for surface plot of sample 2D sweep (VNA)
* press <4> for heatmap plot of sample 2D sweep (VNA)
* press <5> for multi-line slice plot of sample 2D sweep (VNA)
* press <6> for 3D radiation pattern plot of sample 2D sweep (VNA)
*********************************************************
```


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VNA mode:

VNA (mag) mode

In VNA mode we are not capturing a single data point at each position. We are capturing many frequencies at once. This makes a VNA setup very powerful to quickly measure the entire frequency response of the antenna.

The following steps are typically needed to perform a VNA mode measurement:

- Manually configure the VNA with all the sweep settings: start frequency, stop frequency, number of points, power level, IF bandwidth, averaging, etc.
- Set up the displayed trace (Trace1) to the one you want to capture. For a typical VNA, with Port1 on the left and Port2 on the right, the measurement will often be S12 to measure the power from Port2 to Port1.
- Calibrate the system using a Through calibration. Include as many of the cables and adapters as possible, so that you can limit how much you need to de-embed later.
- Save this Cal and System state to the hard drive so it can be loaded when `mbx.py` is launched and ready for measurement.
- The calibration file is specified in `mbx_instrument.py`. For example, for a Keysight VNA, the calibration file is stored in `C:\MILLIBOX\MBX.CSA`. You may need to change this if you save it somewhere else or if the calibration file type for your equipment is different. This depends on which VNA driver you use from `mbx_instrument.py`.

☛ Note: The path for the CSA file or other types of setup file for the VNA needs to be stored on <u>the hard drive of the VNA, not on the hard drive of the PC controlling the VNA</u>

```
    # class attribute for the instrument type (SA,VNA,SG,etc.)
    inst_type = "VNA"

    def init_meas(self):                                                    # initialize VNA

        # save cal state file to C:\MILLIBOX\MBX.CSA or change this file name
        calfile = "C:\\MILLIBOX\\MBX.CSA"

        print("")
```


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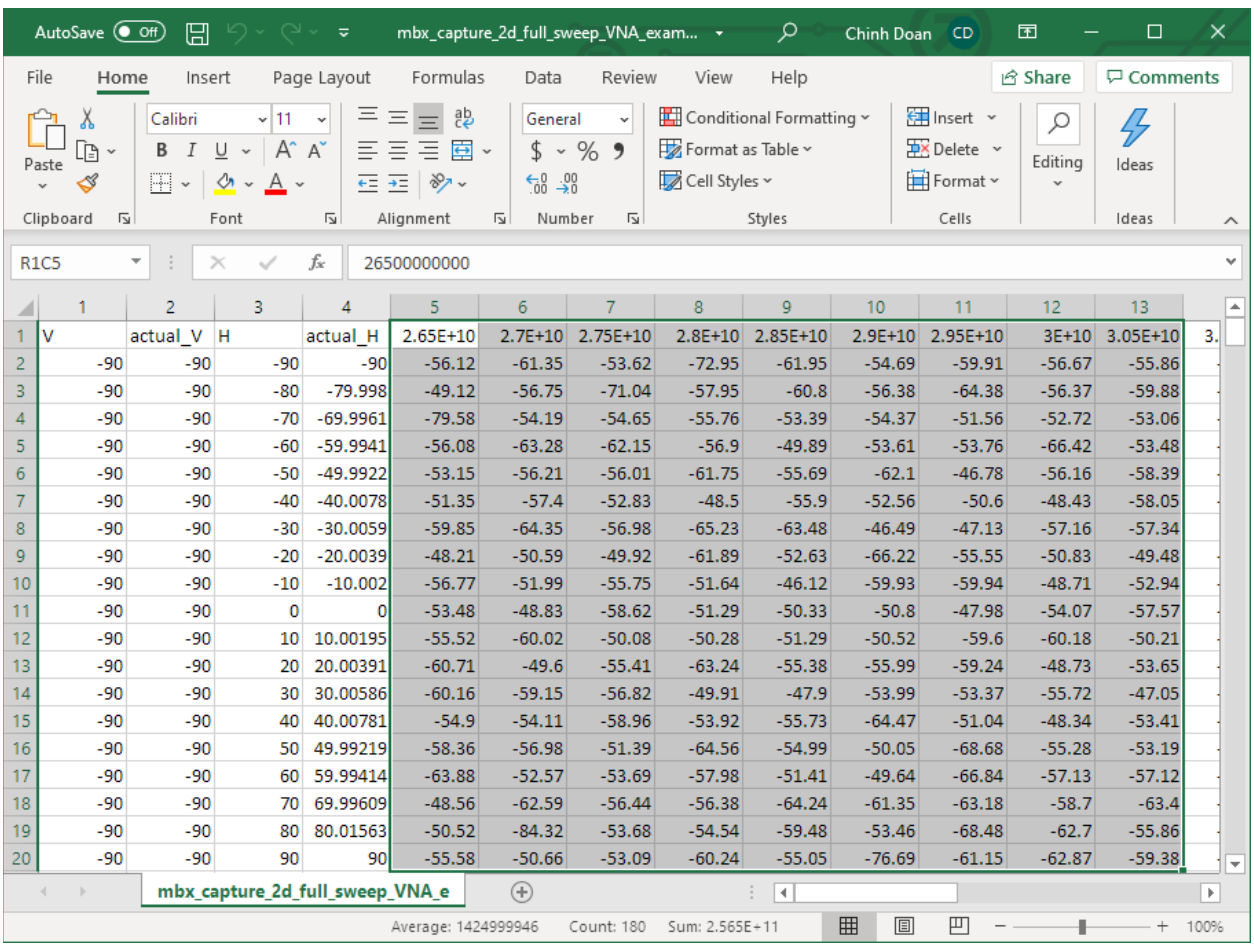
- Connect the cables to the DUT and the receiving horn antenna. The trace that is displayed on the VNA will include the path loss, TX and RX antenna gains, and any additional cable and adapter loss not included in the calibration.
- The setup is now ready to run VNA mode measurements.

When running the 1D, 2D, or HV sweeps in VNA mode, a single shot trigger and capture is performed at each gimbal position, and the data stored in the CSV. For interactive visualization, the power level for a single frequency is plotted and printed on screen in the log. However, at each gimbal position, the CSV file contains all the frequency data with separate columns for each frequency and can be post-processed later. An example of a CSV file from a VNA run is shown below. Note that additional columns of data are included at the end, with the frequency of the measurement in the header on Row 1.



	1	2	3	4	5	6	7	8	9	10	11	12	13
1	V	actual_V	H	actual_H	2.65E+10	2.7E+10	2.75E+10	2.8E+10	2.85E+10	2.9E+10	2.95E+10	3E+10	3.05E+10
2	-90	-90	-90	-90	-56.12	-61.35	-53.62	-72.95	-61.95	-54.69	-59.91	-56.67	-55.86
3	-90	-90	-80	-79.998	-49.12	-56.75	-71.04	-57.95	-60.8	-56.38	-64.38	-56.37	-59.88
4	-90	-90	-70	-69.9961	-79.58	-54.19	-54.65	-55.76	-53.39	-54.37	-51.56	-52.72	-53.06
5	-90	-90	-60	-59.9941	-56.08	-63.28	-62.15	-56.9	-49.89	-53.61	-53.76	-66.42	-53.48
6	-90	-90	-50	-49.9922	-53.15	-56.21	-56.01	-61.75	-55.69	-62.1	-46.78	-56.16	-58.39
7	-90	-90	-40	-40.0078	-51.35	-57.4	-52.83	-48.5	-55.9	-52.56	-50.6	-48.43	-58.05
8	-90	-90	-30	-30.0059	-59.85	-64.35	-56.98	-65.23	-63.48	-46.49	-47.13	-57.16	-57.34
9	-90	-90	-20	-20.0039	-48.21	-50.59	-49.92	-61.89	-52.63	-66.22	-55.55	-50.83	-49.48
10	-90	-90	-10	-10.002	-56.77	-51.99	-55.75	-51.64	-46.12	-59.93	-59.94	-48.71	-52.94
11	-90	-90	0	0	-53.48	-48.83	-58.62	-51.29	-50.33	-50.8	-47.98	-54.07	-57.57
12	-90	-90	10	10.00195	-55.52	-60.02	-50.08	-50.28	-51.29	-50.52	-59.6	-60.18	-50.21
13	-90	-90	20	20.00391	-60.71	-49.6	-55.41	-63.24	-55.38	-55.99	-59.24	-48.73	-53.65
14	-90	-90	30	30.00586	-60.16	-59.15	-56.82	-49.91	-47.9	-53.99	-53.37	-55.72	-47.05
15	-90	-90	40	40.00781	-54.9	-54.11	-58.96	-53.92	-55.73	-64.47	-51.04	-48.34	-53.41
16	-90	-90	50	49.99219	-58.36	-56.98	-51.39	-64.56	-54.99	-50.05	-68.68	-55.28	-53.19
17	-90	-90	60	59.99414	-63.88	-52.57	-53.69	-57.98	-51.41	-49.64	-66.84	-57.13	-57.12
18	-90	-90	70	69.99609	-48.56	-62.59	-56.44	-56.38	-64.24	-61.35	-63.18	-58.7	-63.4
19	-90	-90	80	80.01563	-50.52	-84.32	-53.68	-54.54	-59.48	-53.46	-68.48	-62.7	-55.86
20	-90	-90	90	90	-55.58	-50.66	-53.09	-60.24	-55.05	-76.69	-61.15	-62.87	-59.38

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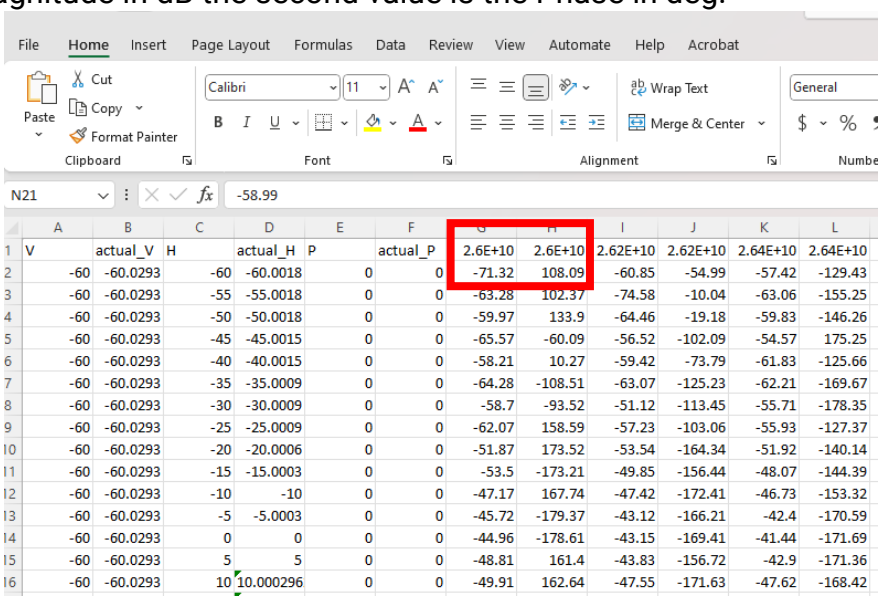
VNA (mag/phase) mode

There is another VNA mode which can be selected from the “y” instrument selection menu option 4: VNA (mag/phase) mode.

In this mode the data set will contain both the magnitude and the phase of each step of the sweep and for each point of the trace.

The data set in the .csv file now contains 2 values for each frequency column: the first one is the Magnitude in dB the second value is the Phase in deg:



	A	B	C	D	E	F	G	H	I	J	K	L
1	V	actual_V	H	actual_H	P	actual_P	2.6E+10	2.6E+10	2.62E+10	2.62E+10	2.64E+10	2.64E+10
2	-60	-60.0293	-60	-60.0018	0	0	-71.32	108.09	-60.85	-54.99	-57.42	-129.43
3	-60	-60.0293	-55	-55.0018	0	0	-63.28	102.37	-74.58	-10.04	-63.06	-155.25
4	-60	-60.0293	-50	-50.0018	0	0	-59.97	133.9	-64.46	-19.18	-59.83	-146.26
5	-60	-60.0293	-45	-45.0015	0	0	-65.57	-60.09	-56.52	-102.09	-54.57	175.25
6	-60	-60.0293	-40	-40.0015	0	0	-58.21	10.27	-59.42	-73.79	-61.83	-125.66
7	-60	-60.0293	-35	-35.0009	0	0	-64.28	-108.51	-63.07	-125.23	-62.21	-169.67
8	-60	-60.0293	-30	-30.0009	0	0	-58.7	-93.52	-51.12	-113.45	-55.71	-178.35
9	-60	-60.0293	-25	-25.0009	0	0	-62.07	158.59	-57.23	-103.06	-55.93	-127.37
10	-60	-60.0293	-20	-20.0006	0	0	-51.87	173.52	-53.54	-164.34	-51.92	-140.14
11	-60	-60.0293	-15	-15.0003	0	0	-53.5	-173.21	-49.85	-156.44	-48.07	-144.39
12	-60	-60.0293	-10	-10	0	0	-47.17	167.74	-47.42	-172.41	-46.73	-153.32
13	-60	-60.0293	-5	-5.0003	0	0	-45.72	-179.37	-43.12	-166.21	-42.4	-170.59
14	-60	-60.0293	0	0	0	0	-44.96	-178.61	-43.15	-169.41	-41.44	-171.69
15	-60	-60.0293	5	5	0	0	-48.81	161.4	-43.83	-156.72	-42.9	-171.36
16	-60	-60.0293	10	10.000296	0	0	-49.91	162.64	-47.55	-171.63	-47.62	-168.42

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Software Instruments:

Nowadays, some instruments have software and hardware components that are separated. The instrument is just a box with limited, if any, user interface, and is controlled from a PC with feature rich software. The software user interface looks and presents all the same functions as a standalone instrument, but it runs on the user machine instead.

In this case it is possible to install the MilliBox controller on the same PC or machine where the instrument front end software is running. The synchronization between the Positioner controller and the instrument is not done through a physical connection like USB, LAN or GPIB but instead it is a software connection between the software component that is established. This virtual connection is done through a SOCKET, meaning a TCP-IP address and a port defined locally.

First, install and run your instrument where MilliBox controller is set up.
On a VNA you should first create the calibration file by attaching the 2 ends on the port 1 to port 2 and go through the calibration menu to store the setup file with the desired trace setting (start frequency, stop frequency, and step size).
In `mbx_instrument.py`, you should find the path where the calibration is expected and store your calibration file at this location.
Usually, the driver expects the file at `C:\MILLIBOX\MBX.xyz` (xyz, depicts different file type for different manufacturers, like .CHX, .ZVK, .CSA etc…)
This is where you should store the file resulting from the setup calibration sequence.

When this is done, on the machine where the software instrument is kept open, run mbx.py.

```
*************************************************
*
*       Mode: NONE
* Instrument: ['SIMULATION']
*  Corr File: ---
*  Save Corr: ---
*     Zigzag: True
*   Position: (0.00, 0.00, 0.00)
*
************* MAIN MENU *************************
```

Here you see that no instruments were found.
On the mbx.py menu type the letter “y” from the keyboard.

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This starts the instrument setting menu:

```
y

Current measurement mode = NONE

************* MEASUREMENT SETUP *************
* press <0> for No Instrument
* press <1> for Spectrum Analyzer only
* press <2> for SigGen + Spectrum Analyzer
* press <3> for VNA (mag)
* press <4> for VNA (mag/phase)
* press <ESC> for no change
*******************************************
VNA (mag) mode selected
```

In our example we select VNA mode because this is what our software instrument is by pressing '3' in the menu.

```
Select VNA VISA address

************** INSTRUMENT LIST **************
  >>>   1) SIMULATION
        2) MANUAL ENTRY (SIMULATION)
*************************************************

Select instrument or enter <0> for no change: 2
Enter equipment VISA address: TCPIP0::127.0.0.1::5001::SOCKET
```

Here the menu offers to enter the Instrument VISA address manually by typing `2) MANUAL ENTRY`.
Then we are asked to enter the instrument address manually.

Common VNA virtual addresses are:
Anritsu ShockLine VNA: TCPIP0::127.0.0.1::5001::SOCKET
Copper Mountain VNA: TCPIP0::127.0.0.1::5025::SOCKET
Keysight Streamline USB VNA: TCPIP0::127.0.0.1::5025::SOCKET

Here we type:
TCPIP0::127.0.0.1::5001::SOCKET
Which is the virtual address of our VNA.
Then press ENTER

```
Select instrument or enter <0> for no change: 2
Enter equipment VISA address: TCPIP0::127.0.0.1::5001::SOCKET

Measurement instrument selected (addr): TCPIP0::127.0.0.1::5001::SOCKET
IDN = ['ANRITSU', 'MS46522B', 'NA', 'V2021.5.2', 'XXXX']
Found!!
['VNA', 'ANRITSU*', 'MS465*', <mbx_instrument.VNA_Anritsu_VectorStar object at 0x000001923AD381F0>]
VNA CONNECTED: 'ANRITSU MS46522B'
initializing equipment
```

Here above we see that the instrument was found and identified correctly.

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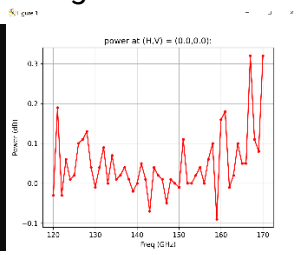
And below it shows that the calibration file was found and loaded.

```
******************** IMPORTANT ********************
  Loading C:\MILLIBOX\MBX.CHX
  Ensure VNA is calibrated, frequencies are set, and
  transmission measurement is on the ACTIVE trace
```

Now we are all set and MilliBox controller is connected to our software instrument.

To be sure we can query the instrument using the letter ‘x’ on the keyboard:

```
x
power at (H,V,P) = (0.0,0.0,0.0):
   0.00GHz :  -21.78
   0.04GHz :  -24.88
   0.09GHz :  -23.19
   0.13GHz :  -20.46
   0.17GHz :  -20.13
   0.21GHz :  -26.33
```



And we see the instrument is responding to our query.
Now, our instrument and MilliBox controller can run on the same machine and communicate properly, our setup is complete, and we can start plotting actual data.

API control:

This software contains an API control interface which can be used to integrate mbx code into a larger automation system seamlessly.
To get started with this, you can browse to: “`C:\SWMilliBox\Examples`”
And find the file: “`mbx_api_example.py`”

In this file you can find the foundation of an API connection from another entity calling `mbx_functions.py` directly. This file has very basic positioner control implemented but it shows how to do it in your environment and context.

To try it we run the code “`mbx_api_example.py`” by typing “`py -3 mbx_api_example.py`” in the command prompt, then the full initialization starts as if we were running from `mbx.py`

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```
C:\SWMilliBox\Examples>python mbx_api_example.py
device = COM4   port = 0
Succeeded to open the port (COM4)!
Succeeded to set the baudrate!
===== Gimbal type CHECK =====
b'[TxRxResult] There is no status packet!'
====> Motor4 (P) motor identified
====> GIM04x identified
====> PH42 Base identified
===== motor configuration CHECK =====
torque for motor 1 is already disabled
torque for motor 2 is already disabled
torque for motor 3 is already disabled
torque for motor 4 is already disabled
flash access set
operating mode H = 4
```

When the diagnostic and initialization phase is complete, we see a simplified menu, where we can set a position on each axis, here we are going for 0°,0°,0°

```
****** GIM motion settings ******
    gim_type = 1
  num_motors = 4
    accuracy = HIGH
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500, 'anglelim': [-180, 180]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10, 'anglelim': [-180, 180]}
           4 = {'model': 1150, 'vel': 97.61125, 'accel': 20, 'anglelim': [-180, 180]}
Device connected
GIM TYPE = HV
Found 4 motor(s)
************************************************
Current position: (0.00, 102.74, 0.00)
> new H pos (999 to quit): 0
> new V pos: 0
> new P pos: 0
************************************************
Current position: (0.00, 0.00, 0.00)
> new H pos (999 to quit):
```

Then we move to 50°, 50°, 50°

```
************************************************
Current position: (0.00, 102.74, 0.00)
> new H pos (999 to quit): 0
> new V pos: 0
> new P pos: 0
************************************************
Current position: (0.00, 0.00, 0.00)
> new H pos (999 to quit): 50
> new V pos: 50
> new P pos: 50
************************************************
Current position: (50.00, 50.01, 49.99)
> new H pos (999 to quit):
```

This example shows that the gimbal can be controlled at API level from a different Software context and shows how to do it.

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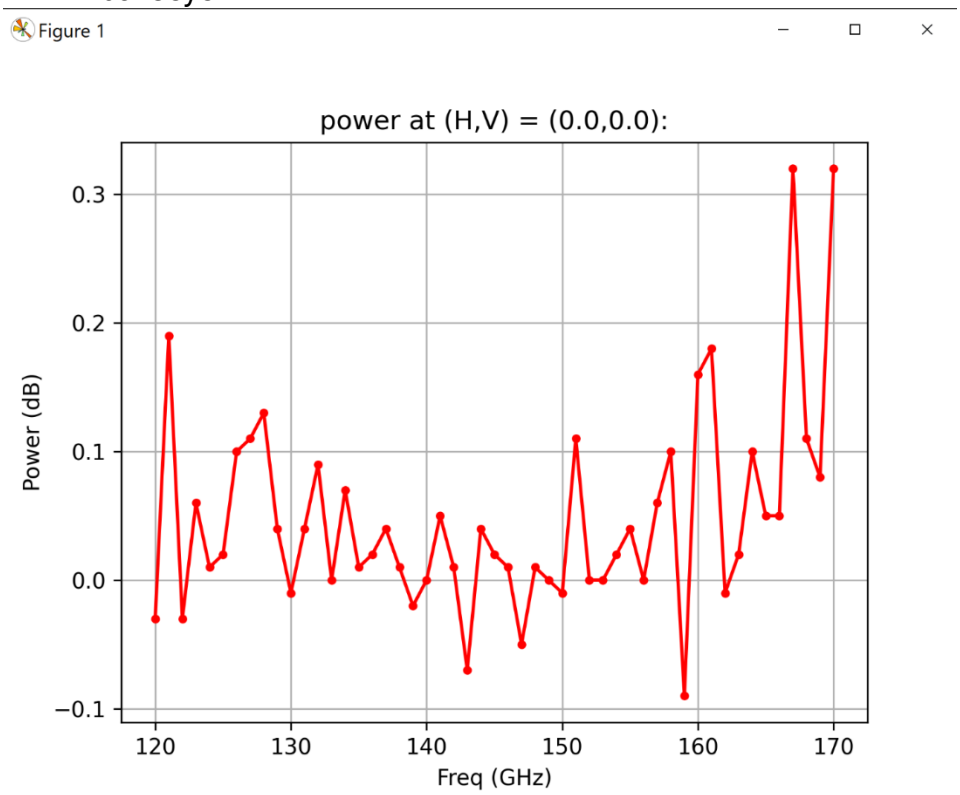
Note: `mbx_functions.py` has a global variable named DEPRECATED_WARNING. It is set to 1 by default. Unless it is set to 0, functions considered “deprecated” will print a warning every time they are used.

Alignment calibration

For GIM05 alignment, see the section “GIM05: Spherical Sweeps” below.

Alignment calibration is required when the hardware has changed or when a new DUT is installed. It does not have to be repeated before every plot. A quick way to see if you need it is just by pressing ‘h’ key with the laser on and checking the alignment of the laser to the bullseye.

- Turn on the laser by plugging the laser USB to a charger or USB receptacle.
- Look at the bullseye mark on the default Horn holder.
- Use the arrow keys in the main menu to coarsely align the laser to the bullseye mark.
- Then press the ‘a’ key on the keyboard and adjust the laser position closer to the bullseye.



- Press the ‘a’ key again to get even closer.

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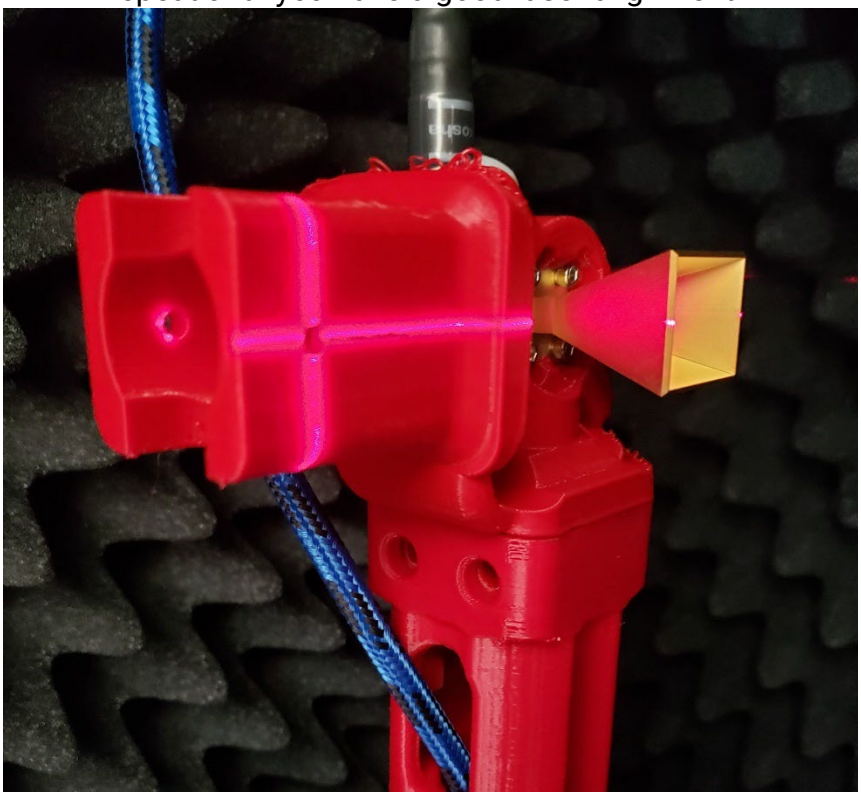
- Repeat until you have a good laser alignment



- When you have a good position, hit “0” on the keyboard, this will store this position as the 0° 0° 0° home position.
- Press ‘s’ key several times to make the motion coarser.
- With the arrow keys move the laser to a grossly misaligned position.
- Then hit the ‘h’ key, this should bring back the laser to alignment with Bullseye.
- This should confirm that the home position has been recorded to the motor absolute sensor.

Note: All motors are limited by software to -180° to +180° motion on both axes to prevent cable tangling. If for some reason you can’t reach the alignment position because you are blocked by the limiter, then you can either reach your target from the other direction (recommended) or use the “0” key to make your position (0,0) such that you can reach further.

Note: the laser has a given life expectancy, so for endurance and safety reasons the laser should not stay powered on continuously.

☛ Note: The calibrated 0°,0° is retained across power cycle as long as the 0°,0° position in H is within +/- 36° of the actual 0.0 calibrated

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GIM04 X-Pol: DUT polarization Controller

X-Pol is an option offered on GIM04 positioners which adds polarization motorized control on top of H and V capabilities.

The X-Pol platform is equipped with several mounting holes such that the DUT can be positioned at its rotation center.
Unlike the other rotation axes, Polarization has no mechanical 0 position, it only has a defined 0 position. This means that the platform is completely circular, and any position can be declared by the user being the arbitrary 0° position. Based on the DUT design and how it mounts on the X-Pol platform, the user decides which position is 0° to be taken for reference when it presses the “0” key. Consequently, all polarization movement and position will be reported from this arbitrary 0°

☛ Note: for good housekeeping, the positioner is brought back to 0° position on all axes including Polarization. One may decide in this case, that the arbitrary position does not need to be the 0° of the antennas but instead the antenna “default” position made for given series of measurements. This way the antenna will stay put in this “default” position until this default position is changed to another one.

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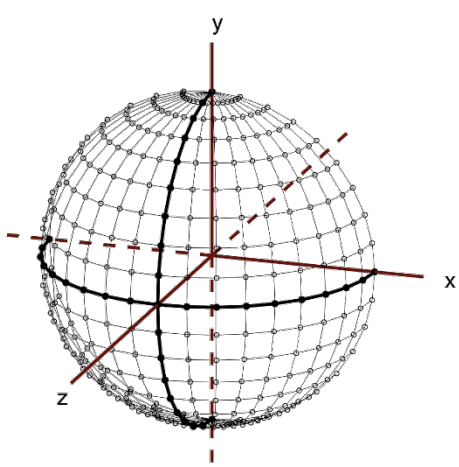
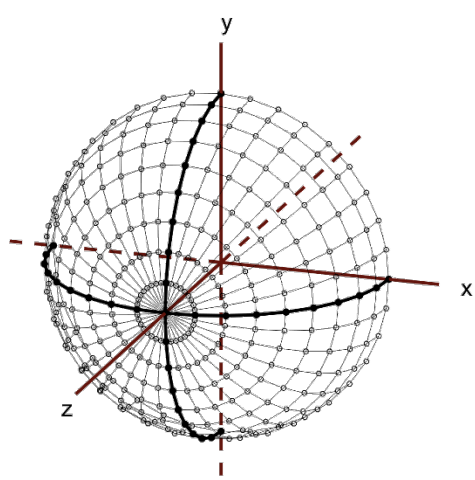
GIM05: Spherical Sweeps

GIM05 offers and different sweep path from earlier positioners, however it generally offers the same capabilities and qualities. There is a fundamental difference between an HV sweep and a Spherical sweep. As a simple analogy, a HV positioner is moving as if the DUT was radiating from the equator on the meridian, then plots following latitudes in V and longitudes in H. For spherical positioners the DUT radiates from the North pole axis, rotates the axis and plots only the latitudes.



HV Plot Coordinates



Spherical Plot Coordinates

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As a result, GIM05 initial alignment is a little bit more complex than other positioners.

- The first step consists of aligning the probe mechanically using the alignment cues on the body of the horn post with the keys [and] on the keyboard and a and s to adjust the step size and narrow down to the exact alignment position.
- The second step is to align the base (Theta Motor) using either mechanical cues or the laser pointer, or a large square with the arrow keys left and right.
- Then align the Phi only motor using the { } keys to finish aligning the 3 axis using mechanical cues.

Alternatively, if the Horn Post probe is aligned, then the electrical auto align function with ‘b’ key from the main menu can be used for the two remaining axes.

Instead of reporting H, V and P, standing for Horizontal, Vertical and Polarization (when available) GIM05 coordinate system reports TH, PH and DPH, which stand for Theta (Base), Phi (Hand + Probe) and Delta Phi (angle offset between Hand and Probe).
Delta Phi is the polarization offset between the DUT and the probe.
Phi is the probe synchronized boresight axis of the DUT.
For most standard measurement, when the probe and DUT are in the same polarization, Delta Phi is 0, and Phi controls the synchronized rotation of both the DUT and the probe facing each other.

Mechanically the DUT and the probe are moving in reverse directions, i.e., when DUT progress clockwise the probe follows counterclockwise as if they were facing each other in a mirror.

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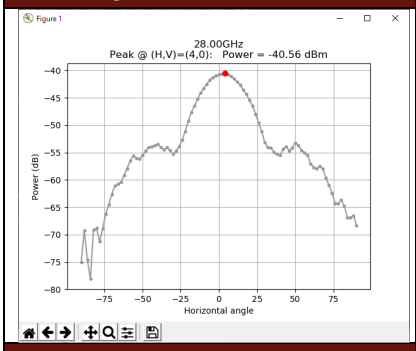
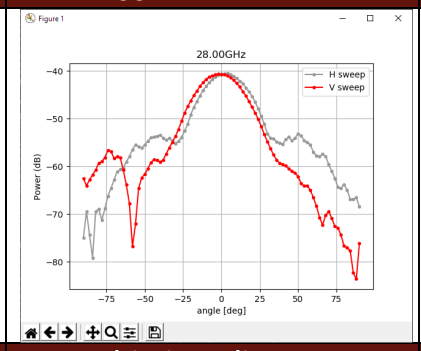
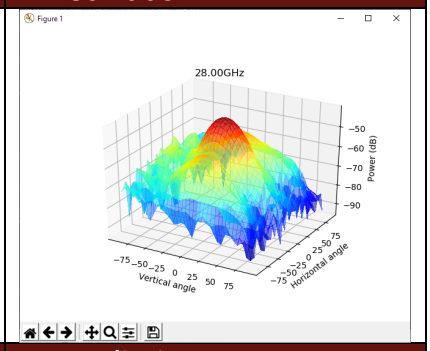
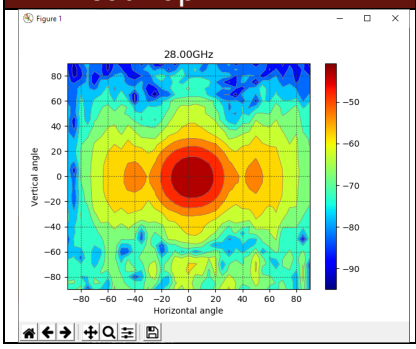
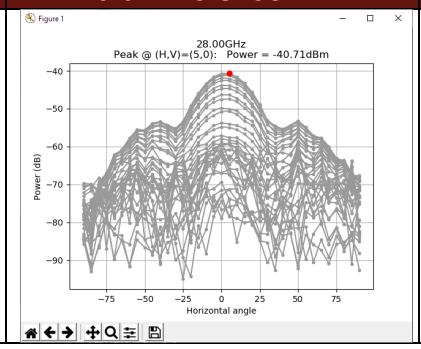
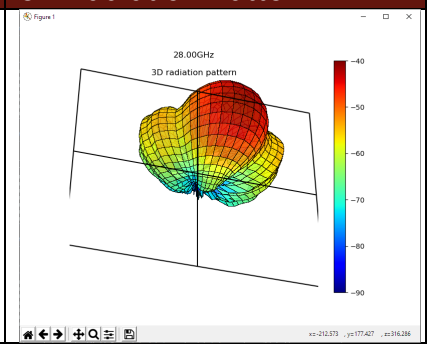
Types of Plots and Sweeps

GIM01, GIM03, GIM04, GIM06 plots

Here is an illustration of the types of plots which can be displayed with those positioners:

1D Line	HV Lines	2D Surface
		
2D Heatmap	**2D Multi-Line Slice**	**3D Radiation Pattern**
		

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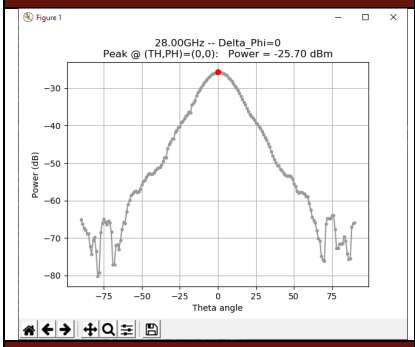
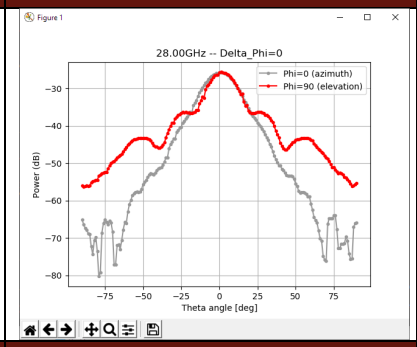
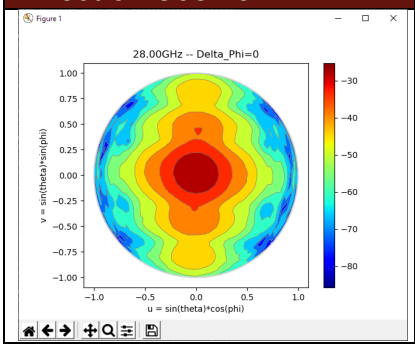
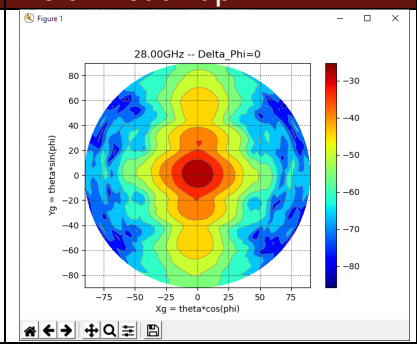
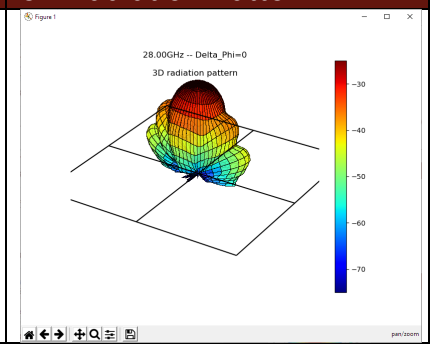
GIM05 plots

Here is an illustration of the types of plots which can be displayed with GIM05 positioners:

1D Line	Az- El Lines	
		
Direction Cosine	**Polar Heatmap**	**3D Radiation Pattern**
		

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New instrument integration strategy

Using mbx_visa_shell.py to create and debug new instrument functions

`mbx_visa_shell.py` is provided as a standalone tool to create and debug new instrument functions.

Run:
C:\SWMilliBox\MBX\python> py -3 mbx_visa_shell.py
You see the initial menu show up.

```
C:\SWMilliBox\MBX\python>py -3 mbx_visa_shell.py

****************** MilliBox VISA Shell Debugger ******************
 This program allows connection to an instrument and interactive
 debugging of the SCPI commands using basic write/read/query.

Save session to 'visa_log.txt'? [Y/N] n

NOT CONNECTED :: <C>onnect, E<X>it --> c
C
```

The first question is about whether you want to log the session in a log file, which can be very useful to get support from MilliBox or the instrument manufacturer.

Here pressing C will bring the following menu:

```
NOT CONNECTED :: <C>onnect, E<X>it --> c
C

************** INSTRUMENT LIST **************
      0) MANUAL ENTRY
      1) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
      2) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
      3) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
      4) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
      5) ASRL3::INSTR
*********************************************

Select instrument: 3
```

In this example we select ‘3’ which is our Spectrum analyzer

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```
NOT CONNECTED :: <C>onnect, E<X>it --> c
C

*************** INSTRUMENT LIST ***************
      0) MANUAL ENTRY
      1) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
      2) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
      3) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
      4) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
      5) ASRL3::INSTR
***********************************************

Select instrument: 3
3

Measurement instrument selected: TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR

CONNECTED to TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR :: <W>rite, <Q>uery, <R>ead, <T>imeout, <C>onnect, E<X>it -->
```

Now we are connected, the menu offers some VISA type commands which we can send to our instrument, we can Read, Write, Query, Timeout, Connect, or Exit the program.

In this simple example we want to change the Marker 1 frequency. From the user Manual of this instrument, we find the correct writing command to set the marker frequency.
Which is a write command.
We type “W” and press enter.

```
C:\SWMilliBox\MBX\python>py -3 mbx_visa_shell.py

****************** MilliBox VISA Shell Debugger ******************
 This program allows connection to an instrument and interactive
 debugging of the SCPI commands using basic write/read/query.

Save session to 'visa_log.txt'? [Y/N] n

NOT CONNECTED :: <C>onnect, E<X>it --> c
C

*************** INSTRUMENT LIST ***************
      0) MANUAL ENTRY
      1) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
      2) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
      3) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
      4) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
      5) ASRL3::INSTR
***********************************************

Select instrument: 3
3

Measurement instrument selected: TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR

CONNECTED to TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR :: <W>rite, <Q>uery, <R>ead, <T>imeout, <C>onnect, E<X>it --> w
W
```

Now we can issue the command at the prompt `:CALC:MARK1:X 40000000000` to set our marker at 40GHz

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```
C:\SWMilliBox\MBX\python>py -3 mbx_visa_shell.py

******************* MilliBox VISA Shell Debugger *******************
 This program allows connection to an instrument and interactive
 debugging of the SCPI commands using basic write/read/query.

Save session to 'visa_log.txt'? [Y/N] n

NOT CONNECTED :: <C>onnect, E<X>it --> c
C

*************** INSTRUMENT LIST ***************
      0) MANUAL ENTRY
      1) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
      2) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
      3) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
      4) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
      5) ASRL3::INSTR
***********************************************

Select instrument: 3
3

Measurement instrument selected: TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR

CONNECTED to TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR :: <W>rite, <Q>uery, <R>ead, <T>imeout, <C>onnect, E<X>it --> w
W
Write --> :CALC::MARK1::X 40000000000
:CALC::MARK1::X 40000000000
```

We see that the command went through, and we check on the Spectrum Analyzer that we have a marker 1 at 40GHz.

Now if we want to read the value of this marker, we need to make a query so we press Q at the prompt and press enter.
Then at the prompt we type the command to read the marker 1 on this instrument
`:CALC:MARKER1:Y?`

```
W
Write --> :CALC::MARK1::X 40000000000
:CALC::MARK1::X 40000000000

CONNECTED to TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR :: <W>rite, <Q>uery, <R>ead, <T>imeout, <C>onnect, E<X>it --> q
Q
Query --> :CALC:MARKER1:Y?
:CALC:MARKER1:Y?
Reply --> '-5.8307E+01
'
CONNECTED to TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR :: <W>rite, <Q>uery, <R>ead, <T>imeout, <C>onnect, E<X>it -->
```

We got a response from the instrument telling us the value of the marker is
-58.307 dB
Which is the value we see on the instrument.

Another very important query for driver identification is the `*IDN?` Command which we use later-on during the instrument integration section is shown here:

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```
****************** MilliBox VISA Shell Debugger ******************
 This program allows connection to an instrument and interactive
 debugging of the SCPI commands using basic write/read/query.

Save session to 'visa_log.txt'? [Y/N] n

NOT CONNECTED :: <C>onnect, E<X>it --> c
C

************** INSTRUMENT LIST **************
      0) MANUAL ENTRY
      1) TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR
      2) TCPIP0::A-N5183B-281258.laurent::inst0::INSTR
      3) TCPIP0::K-N9010B-71055.laurent::hislip0::INSTR
      4) TCPIP0::K-N9010B-71055.laurent::inst0::INSTR
      5) ASRL3::INSTR
*********************************************

Select instrument: 1
1

Measurement instrument selected: TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR

CONNECTED to TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR :: <W>rite, <Q>uery, <R>ead, <T>imeout, <C>onnect, E<X>it --> q
Q
Query --> *IDN?
*IDN?
Reply --> 'Agilent Technologies, N5183B, MY57281258, B.01.86
'
CONNECTED to TCPIP0::A-N5183B-281258.laurent::hislip0::INSTR :: <W>rite, <Q>uery, <R>ead, <T>imeout, <C>onnect, E<X>it -->
```

You can see that `*IDN?` query returns:
Agilent Technologies, N5183B, MY57281258, B.01.86

We are interested in `'Agilent Technologies'` which is our manufacturer name and `'N5183B'` which is our instrument model number which we use to identify the correct driver for our instrument.

This way we can create and test new commands and new functions for our test setup. Even if we have to create a new instrument from scratch, the `mbx_visa_shell.py` can be very handy to test out features and the communication over pyVisa. Most importantly we can test the syntax of our SCPI commands. Then we can add those commands to `mbx_instrument.py`.

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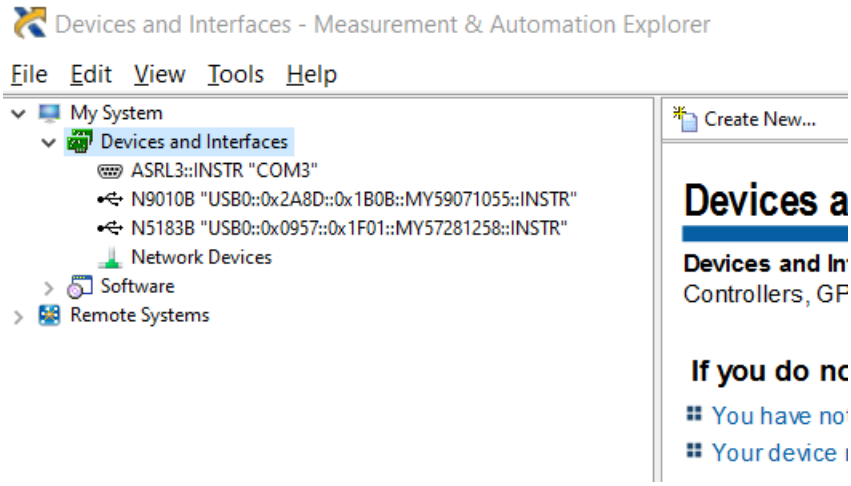
Basic steps for attaching a new instrument

The provided software defines the framework to be able to integrate any instrument you would want to attach to the 3D positioner motion.
The instrument can of course be a Spectrum Analyzer or a VNA, but this could be expanded to be other types of instruments like a thermal sensor or power supply provided they have VISA control. By extension, this framework could allow you to communicate with your own DUT, for example one may want to record phase vectors as part of the radiation pattern. This is particularly important for Radar design where key metrics are provided by the DUT itself not by an external instrument. Below are the steps for a VISA capable instrument setup.

1) Instrument VISA address

The first step is to get your instrument attached to VISA interface.
Your instrument can be physically connected to the machine running mbx.py using USB or LAN or GPIB connection.
You can use a VISA tool like NiMax or other tools to check that the address of your instrument is discovered and identified.



Here you can see that we have 2 instruments connected where the VISA addresses are discovered.
Now this means your instrument is discoverable by MilliBox software.

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2) Instrument ID parsing

`mbx_instrument.py` includes several drivers for common instrument types and brands which are automatically selected by recognition of the type, brand and model number retrieved from the instrument IDN query.

The common query command is `*IDN?` for all vendors we know of.
From it `mbx_instrument.py` function `query_idn(addr)` can enquire the address and ask for this instrument to identify itself.
This query returns a string which `query_idn(addr)` breaks into an array of four parameters:
[manufacturer, model, serial no, firmware ver]
Based on those, MilliBox software decides a driver matching this instrument.
This is what appears when the IDN query returns an instrument recognized in the driver list:

```
************* MEASUREMENT SETUP *************
* press <0> for No Instrument
* press <1> for Spectrum Analyzer only
* press <2> for SigGen + Spectrum Analyzer
* press <3> for VNA
* press <ESC> for no change
*********************************************
Spectrum Analyzer mode selected
Select Spectrum Analyzer VISA address
************** INSTRUMENT LIST **************
      a) SIMULATION
      b) USB0::0x2A8D::0x1B0B::MY59071055::INSTR
  >>> c) USB0::0x0957::0x1F01::MY57281258::INSTR
*********************************************

Select instrument or press <ENTER> for no change

Measurement instrument selected (addr): USB0::0x2A8D::0x1B0B::MY59071055::INSTR
IDN = ['KEYSIGHT TECHNOLOGIES', 'N9010B', 'MY59071055', 'A.25.05']
Found!!
['SA', 'KEYSIGHT*', 'N9010*', <mbx_instrument.SA_Keysight_EXA object at 0x000000001CE25C18>]
SA CONNECTED: 'KEYSIGHT TECHNOLOGIES N9010B'
initializing equipment
measurement mode and equipment saved to file

****************************************************
*
*       Mode: SA
* Instrument: ['USB0::0x2A8D::0x1B0B::MY59071055::INSTR']
*   Accuracy: HIGH
*   Position: (-0.04, 0.00, 0.04)
*
************* MAIN MENU ***************************
```


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But if a matching driver does not exist the code will show the following warning:

```
Current measurement mode = SA

************** MEASUREMENT SETUP **************
* press <0> for No Instrument
* press <1> for Spectrum Analyzer only
* press <2> for SigGen + Spectrum Analyzer
* press <3> for VNA
* press <ESC> for no change
***********************************************
Spectrum Analyzer mode selected
Select Spectrum Analyzer VISA address
*************** INSTRUMENT LIST ***************
      a) SIMULATION
      b) USB0::0x2A8D::0x1B0B::MY59071055::INSTR
  >>> c) USB0::0x0957::0x1F01::MY57281258::INSTR
***********************************************

Select instrument or press <ENTER> for no change

Measurement instrument selected (addr): USB0::0x2A8D::0x1B0B::MY59071055::INSTR
IDN = ['KEYSIGHT TECHNOLOGIES', 'N9010B', 'MY59071055', 'A.25.05']
Found!!
[['SA', 'KEYSIGHT*', '*', <mbx_instrument.SA_Keysight_Generic object at 0x000000001BB8804B>]
#######################  !! WARNING !!  #######################
##                                                           ##
Unable to find SA driver for mfg/model: KEYSIGHT TECHNOLOGIES / N9010B
Using class: <class 'mbx_instrument.SA_Keysight_Generic'>
##                                                           ##
##   Attempting to use DEFAULT driver. If driver works, add  ##
##   your equipment model to the White List of recognized    ##
##   equipment to remove this WARNING message.               ##
###############################################################

Press ENTER to continue...

SA CONNECTED: 'KEYSIGHT TECHNOLOGIES N9010B'
initializing equipment
measurement mode and equipment saved to file

***************************************************
*
*       Mode: SA
* Instrument: ['USB0::0x2A8D::0x1B0B::MY59071055::INSTR']
*   Accuracy: HIGH
*   Position: (-0.01, 0.00, 0.00)
*
************** MAIN MENU **************************
```

This shows the driver needs to be created

Note: most manufacturers have identical VISA interface and SCPI command set so it is highly likely that the only thing you must do is to register your IDN in the instrument whitelist which is explained in step 4). But in case your new instrument has no compatible driver at all, let's proceed to step 3)

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3) Testing a new instrument against existing driver

In many instances the new instrument you connect is already completely or partially compatible with existing drivers. This is because 1) instrument manufacturers have SCPI commands syntax that are widely used across all their models and 2) because MilliBox software uses very generic SCPI commands which are not model specific.
To proceed with this test, when your instrument is connected to your control machine, run the standalone code `mbx_test_instrument.py`.

```
*************  MILLIBOX INSTRUMENT DRIVER DIAGNOSTICS  *************
*                                                                 *
* This program checks the driver implementation for the equipment *
* control in mbx_instrument.py and used by mbx.py. All of the     *
* necessary commands are exercised.                               *
*                                                                 *
* Adjust the SCPI commands and sequence until no error occurs.    *
*                                                                 *
*******************************************************************

All connected devices:
----------------------
a) USB0::0x2A8D::0x1B0B::MY59071055::INSTR
b) USB0::0x0957::0x1F01::MY57281258::INSTR
c) ASRL5::INSTR
Select the instrument address:
```

Now you have a list of connected instruments, and you need to test an existing driver for it.
In our case we select ‘a’ which is our new spectrum analyzer

```
*******************************************************************

All connected devices:
----------------------
a) USB0::0x2A8D::0x1B0B::MY59071055::INSTR
b) USB0::0x0957::0x1F01::MY57281258::INSTR
c) ASRL5::INSTR
Select the instrument address: a

Select the equipment type:
---------------------------
a) SA
b) SG
c) VNA
Select the equipment type: a
VISA address = USB0::0x2A8D::0x1B0B::MY59071055::INSTR
IDN = ['KEYSIGHT TECHNOLOGIES', 'N9010B', 'MY59071055', 'A.25.05']
Found!!
['SA', 'KEYSIGHT*', '*', <mbx_instrument.SA_Keysight_Generic object at 0x000001E6E3B788B0>]
#######################  !! WARNING !!  #######################
##                                                           ##
Unable to find SA driver for mfg/model: KEYSIGHT TECHNOLOGIES / N9010B
Using class: <class 'mbx_instrument.SA_Keysight_Generic'>
##                                                           ##
##   Attempting to use DEFAULT driver. If driver works, add  ##
##   your equipment model to the White List of recognized    ##
##   equipment to remove this WARNING message.               ##
###############################################################

Press ENTER to continue...
```


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Then we select ‘a’ again because the only thing we know about our instrument is that it is a Spectrum Analyzer.
The warning tells us we are not sure that the driver for our instrument exist because we don’t have direct match on the model number.
So we press ENTER to proceed and see that we can retrieve the ID of our instrument.

```
Press ENTER to continue...

SA CONNECTED: 'KEYSIGHT TECHNOLOGIES N9010B'

testing: Spectrum analyzer mode
Press enter to continue...
```

We press ENTER again to continue our test.
We are prompted to insert a frequency:
In our case we want to try 40GHz so we type 40 000 000 000 when prompted.

```
testing: Spectrum analyzer mode
Press enter to continue...

enter frequency [Hz]: 40000000000

>> init_meas()...
Press enter to continue...
```

Now we are prompted for every SCPI command implemented in the driver to see if they all go through properly. We check on the instrument display that the expected result is obtained.

```
SA CONNECTED: 'KEYSIGHT TECHNOLOGIES N9010B'

testing: Spectrum analyzer mode
Press enter to continue...

enter frequency [Hz]: 40000000000

>> init_meas()...
Press enter to continue...
done
0.00 sec to initalize

>> get_status()...
Press enter to continue...
done
status = 0

>> fix_status()...
Press enter to continue...
done
0.00 sec to fix status

>> enable_marker(1)...
Press enter to continue...
done

>> set_freq(40000000000.000000)...
Press enter to continue...
done

>> set_marker_freq(1, 40000000000.000000)...
Press enter to continue...
done

>> get_marker_freq(1)...
Press enter to continue...
done
freq = 40000000000.0

>> get_marker(1)...
Press enter to continue...
done
pwr = -59.346
*************  DONE WITH INSTRUMENT DRIVER DIAGNOSTICS  *************
```

Here we are lucky because all our SCPI commands worked well. Now we know our instrument works with the existing driver, so we are left to add our instrument in the whitelist, explained below. This way the code will know that this instrument is attached automatically to this driver.

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In the following sequence we see that most commands worked as expected but something went wrong, our intention was to get our marker 1 at 28GHz but instead it stayed at 40GHz, and we see that the value of our marker is wrong. We checked on the Spectrum Analyzer screen to see that there are some setting issues. In such a case we need to rework our SCPI commands one by one or those which fail using the method explained below.

```
SA CONNECTED: 'KEYSIGHT TECHNOLOGIES N9010B'

testing: Spectrum analyzer mode
Press enter to continue...

enter frequency [Hz]: 28000000000

>> init_meas()...
Press enter to continue...
done
0.00 sec to initalize

>> get_status()...
Press enter to continue...
done
status = 0

>> fix_status()...
Press enter to continue...
done
0.00 sec to fix status

>> enable_marker(1)...
Press enter to continue...
done

>> set_freq(28000000000.000000)...
Press enter to continue...
done

>> set_marker_freq(1, 28000000000.000000)...
Press enter to continue...
done

>> get_marker_freq(1)...
Press enter to continue...
done
freq = 40000000000.0

>> get_marker(1)...
Press enter to continue...
done
pwr = 9.91e+37
*************  DONE WITH INSTRUMENT DRIVER DIAGNOSTICS  *************
```

4) Creating a new driver and new commands.

First you should decide if this instrument is a Signal Generator (SG), a Spectrum Analyzer (SA), a Vector Network Analyzer (VNA), or something else.
If it is a SG, SA or VNA you can re-use those types which already exist, if it is something else you need to create a new instrument type and class and make all the commands from scratch.

Let's assume your new instrument is a SA.

In `mbx_instrument.py`, copy the entire instrument class:

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```
class SA_Keysight_EXA(SA_Generic):

    # include any specific Keysight EXA commands here
    def SA_Keysight_EXA_specific_func(self):
        return
etc…
and all its functions
```

and call it something like:

```
class SA_MyNewInstrument(SA_Generic):

    # class attribute for the instrument type (SA,VNA,SG,etc.)
    inst_type = "SA"
etc…
```

Now this is where `mbx_visa_shell.py` comes very handy, run it on your controller machine and test all the commands in the class;
class SA_Generic(Instrument):

If they all work as expected, great you only need to register your instrument in the whitelist as shown in step 4).
If not, then you need to modify their syntax. For this, copy this SCPI function to your new class and define this function with its new syntax

for example, in `SA_Generic` you see:

```
def enable_marker(self, num):   # enable marker (num)
    self.write(":CALC:MARK%d:MODE POS" % num)
    return
```

So in mbx_visa_shell.py you test the write command :CALC:MARK1:MODE POS

But let's say hypothetically, it did not work and when you check the instrument user manual SCPI commands set it should instead be written `:CALC:MARK1:MODE X` to work

then in your class SA_MyNewInstrument(SA_Generic)
create a substitute function:

```
def enable_marker(self, num):   # enable marker (num)
    self.write(":CALC:MARK%d:MODE X" % num)
    return
```


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when all the functions in SA_Generic and in SA_MyNewInstrument (SA_Generic) are working as expected in the shell, you are ready to register your new instrument driver.

Do not replace or modify existing functions in generic or specific existing driver class directly to accommodate your instrument. This would break the code in case you want to use other instruments in the future. Instead copy paste and modify existing functions in a new class of instrument, this way the code integrity is maintained for future use. When your instrument is used it will use your new commands but when another instrument is used it will use the legacy command and expand your setup capabilities

Note: you use this same method if you want to add new functions altogether. Then you can call them from `mbx_functions.py` and add new capabilities this way and there are no limits to the functionalities you can expand in MilliBox software framework.

5) Registering a new driver to the instrument whitelist

Now our new instrument VISA commands are all working, we are left with registering our new driver to our framework.
Use `mbx_visa_shell.py` and query your instrument address with the command `*IDN?` as explained in the section above, Identify the manufacturer and model number in the string:
For example, the query returns: `MANUF, XXYYY, 12345, 6789`
Go to the end of mbx_instrument.py
And see the driver whitelist:

```
##########################################
# Instrument driver list
##########################################

# specific known and tested instrument drivers
driver_list = [
  ['SA',     'KEYSIGHT*','N9010*',   SA_Keysight_EXA()],
  ['SA',     'ROHDE*',   'FSW*',     SA_RohdeSchwarz_FSW()],
  ['VNA',    'KEYSIGHT*','E8361*',   VNA_Keysight_PNA()],
  ['VNA',    'KEYSIGHT*','N5247*',   VNA_Keysight_PNA()],
  ['VNA',    'ANRITSU*', 'MS464*',   VNA_Anritsu_VectorStar()],
  ['VNA',    'ROHDE*',   'ZVA*',     VNA_RohdeSchwarz_ZVA()],
  ['SG',     'AGILENT*', 'N5183*',   SG_Keysight_MXG()],
]
```


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And add our new instrument identification in the driver list:

```
##########################################
# Instrument driver list
##########################################

# specific known and tested instrument drivers
driver_list = [
  ['SA'      'MANUF*',   'XXYYY*   SA_MyNewInstrument()],
  ['SA',     'KEYSIGHT*','N9010*', SA_Keysight_EXA()],
  ['SA',     'ROHDE*',   'FSW*',   SA_RohdeSchwarz_FSW()],
…
```

Now we are ready to run mbx.py and use the ‘y’ instrument driver selector, choose “SA” mode or “SG+SA” mode (in our example) or the mode which match your instrument type and you should be able to select your new driver form the list, or it should be selected automatically.

Now all the functions in the mbx.py code will use our new instrument driver.

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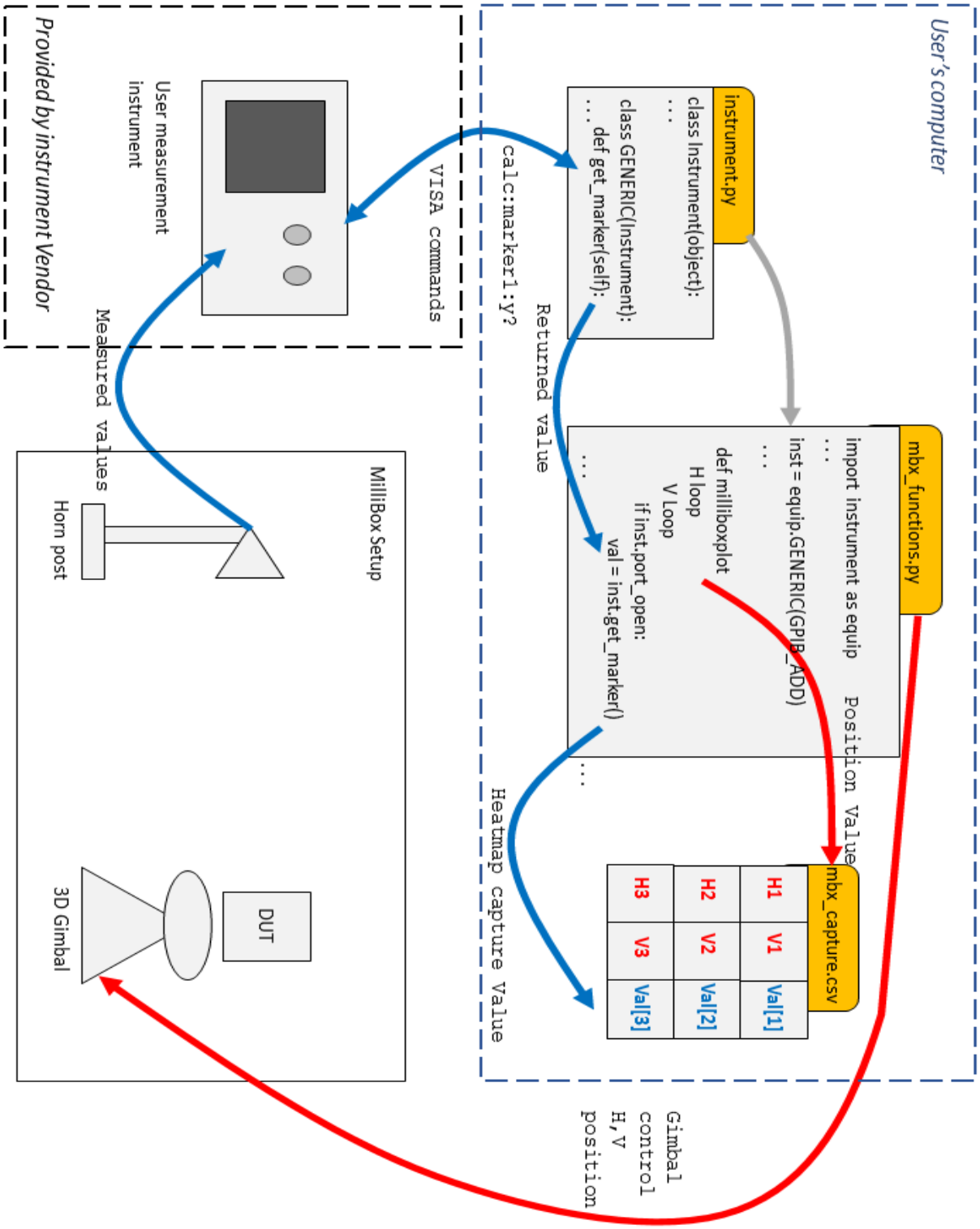
This is a simplified visual representation of an integrated setup:



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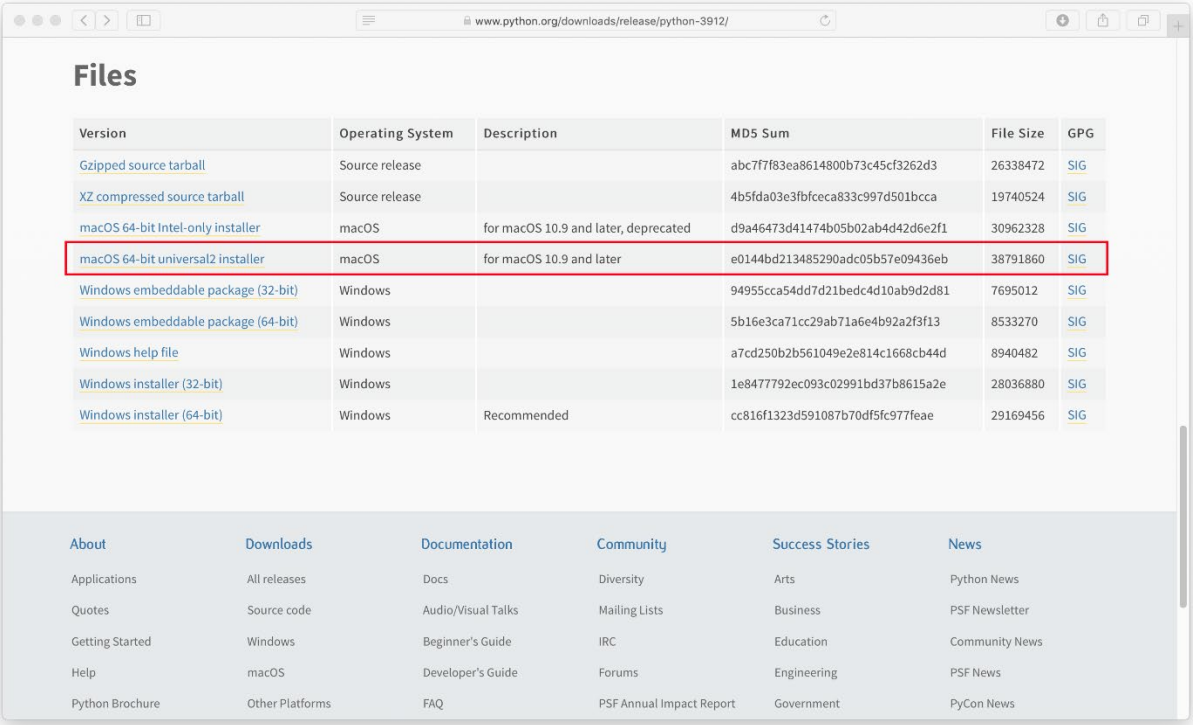
Advanced installation, control, and troubleshooting:

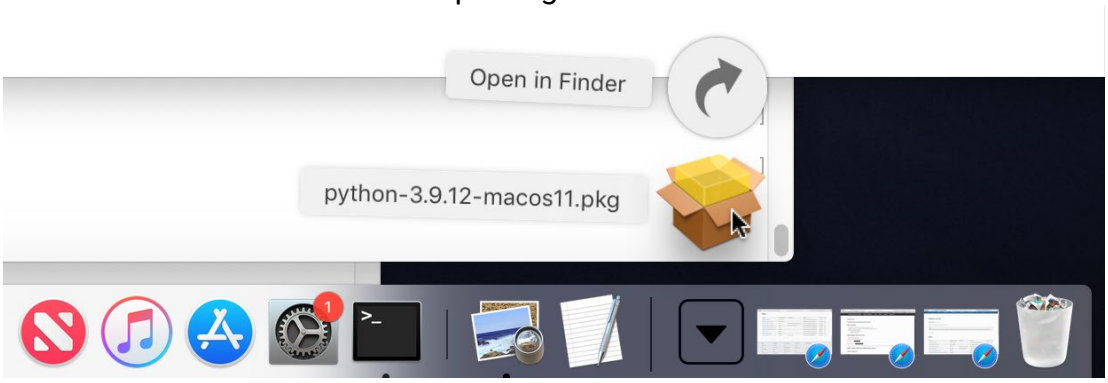
Alternative installation:

MacOS installation.

If you want to use MilliBox controller on a MacOS operating system, follow these steps: On the internet, browse to a Python version you want to install, in this example we are using version 3.9.12



In the list you can choose “macOS 64-bit universal2 installer” if your machine is OS X 10.9 or later. And download the package.



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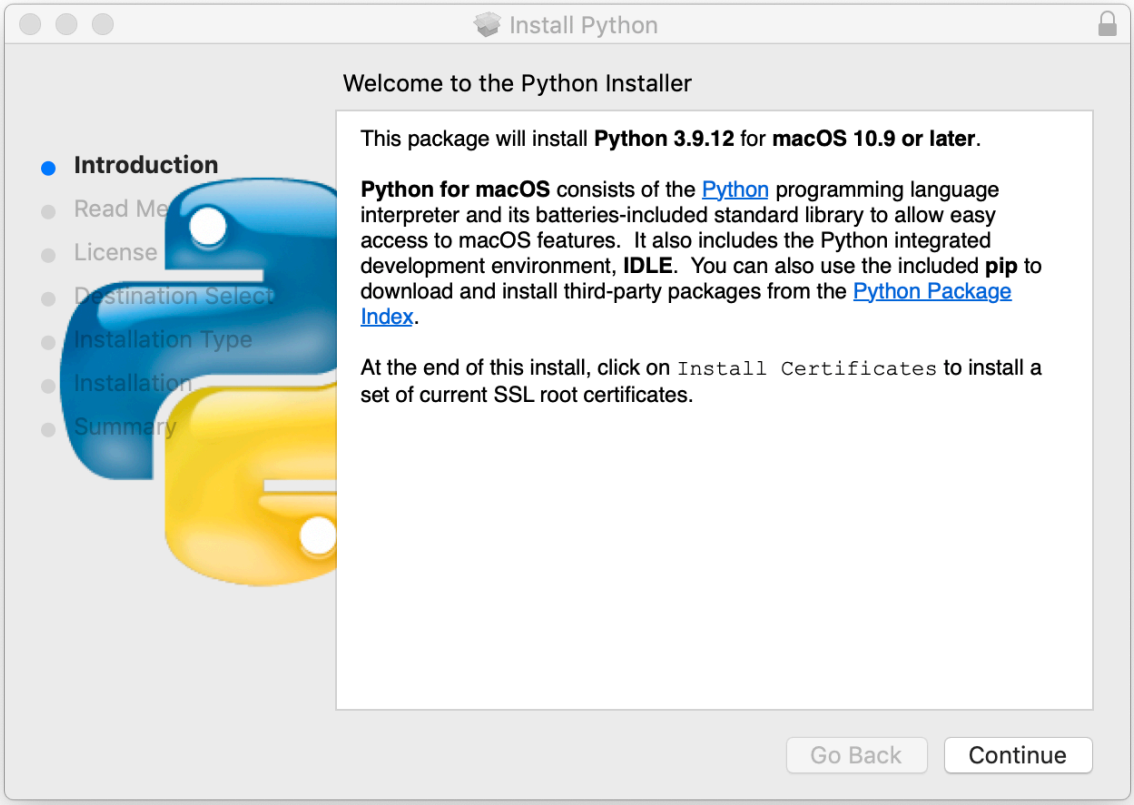
Install with the default settings.



Go through the installation process until completed.

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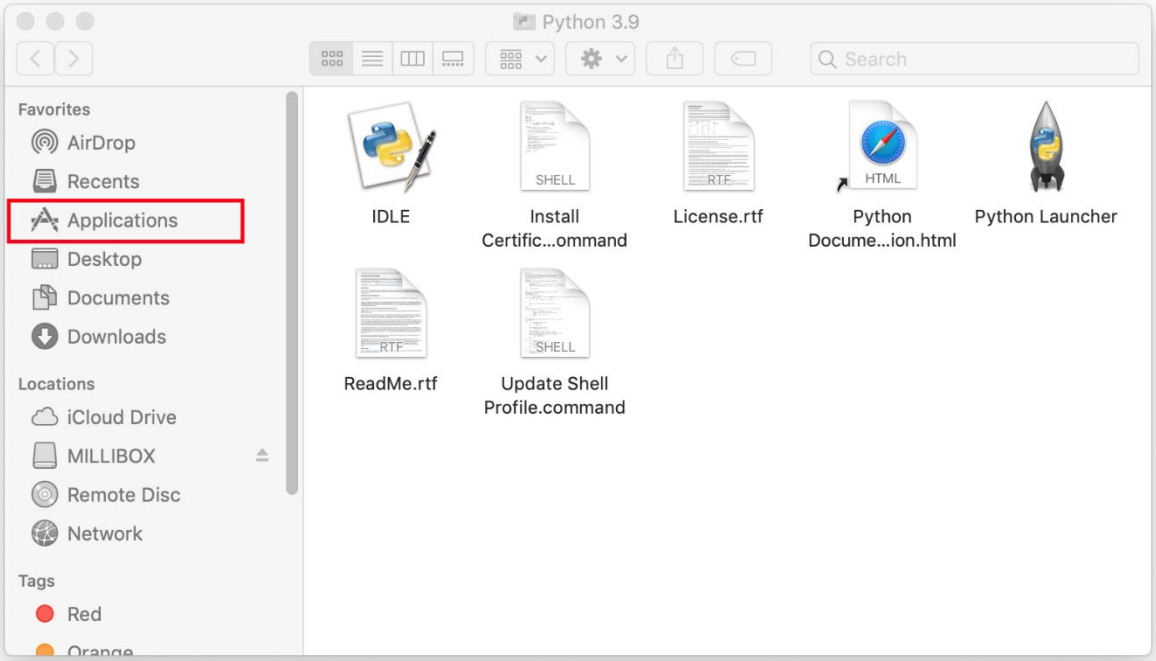
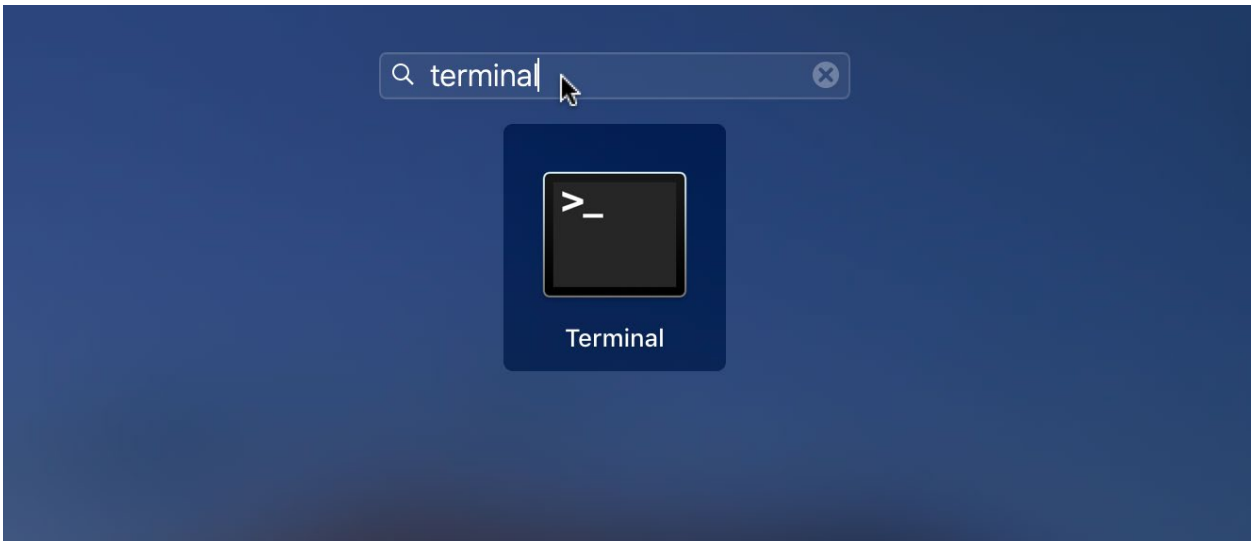
After installation, a Python 3.9 folder will be created in the Applications folder.



Then, open a shell terminal window by clicking on the Launchpad and searching for "terminal":



In the terminal window, type: `which python3` to ensure the python installation was successful. Links to the python executables should be found in /usr/local/bin.
Then type: `which pip3` to ensure pip is responding and type: `pip3 install --upgrade pip` like shown below to make sure the updater is the latest version.

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```
admins-MacBook-Pro:~ admin$ which python3
/usr/local/bin/python3
admins-MacBook-Pro:~ admin$ which pip3
/usr/local/bin/pip3
admins-MacBook-Pro:~ admin$ pip3 install --upgrade pip
Requirement already satisfied: pip in /Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-packages (22.0.4)
```

At this point we can add our necessary python modules and dependencies.
Type: `pip3 install matplotlib` in the terminal

```
admins-MacBook-Pro:~ admin$ pip3 install matplotlib
Collecting matplotlib
  Using cached matplotlib-3.5.1-cp39-cp39-macosx_10_9_x86_64.whl (7.3 MB)
Requirement already satisfied: numpy>=1.17 in /Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-packages (from matplotlib) (1.2
2.3)
Collecting pillow>=6.2.0
  Using cached Pillow-9.1.0-cp39-cp39-macosx_10_9_x86_64.whl (3.1 MB)
Collecting pyparsing>=2.2.1
  Using cached pyparsing-3.0.8-py3-none-any.whl (98 kB)
Collecting python-dateutil>=2.7
  Using cached python_dateutil-2.8.2-py2.py3-none-any.whl (247 kB)
Collecting kiwisolver>=1.0.1
  Using cached kiwisolver-1.4.2-cp39-cp39-macosx_10_9_x86_64.whl (65 kB)
Collecting cycler>=0.10
  Using cached cycler-0.11.0-py3-none-any.whl (6.4 kB)
Collecting packaging>=20.0
  Using cached packaging-21.3-py3-none-any.whl (40 kB)
Collecting fonttools>=4.22.0
  Using cached fonttools-4.32.0-py3-none-any.whl (900 kB)
Collecting six>=1.5
  Using cached six-1.16.0-py2.py3-none-any.whl (11 kB)
Installing collected packages: six, pyparsing, pillow, kiwisolver, fonttools, cycler, python-dateutil, packaging, matplotlib
Successfully installed cycler-0.11.0 fonttools-4.32.0 kiwisolver-1.4.2 matplotlib-3.5.1 packaging-21.3 pillow-9.1.0 pyparsing-3.0.8 python-dateuti
l-2.8.2 six-1.16.0
admins-MacBook-Pro:~ admin$
```

Then type: `pip3 install pyvisa`

```
admins-MacBook-Pro:~ admin$ pip3 install pyvisa
Collecting pyvisa
  Using cached PyVISA-1.11.3-py3-none-any.whl (189 kB)
Collecting typing-extensions
  Using cached typing_extensions-4.1.1-py3-none-any.whl (26 kB)
Installing collected packages: typing-extensions, pyvisa
Successfully installed pyvisa-1.11.3 typing-extensions-4.1.1
```

Then type: `pip3 install pyvisa-py`

```
admins-MacBook-Pro:~ admin$ pip3 install pyvisa-py
Collecting pyvisa-py
  Using cached PyVISA_py-0.5.2-py3-none-any.whl (56 kB)
Requirement already satisfied: typing-extensions in /Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-packages (from pyvisa-py)
 (4.1.1)
Requirement already satisfied: pyvisa>=1.11.0 in /Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-packages (from pyvisa-py) (1
.11.3)
Installing collected packages: pyvisa-py
Successfully installed pyvisa-py-0.5.2
```

Then type: `pip3 install scipy`

```
admins-MacBook-Pro:python admin$ pip3 install scipy
Collecting scipy
  Downloading scipy-1.15.1-cp312-cp312-macosx_10_13_x86_64.whl.metadata (61 kB)
Requirement already satisfied: numpy<2.5,>=1.23.5 in /Library/Frameworks/Python.framework/Versions/3.12/lib/python3.12/site-packages (from scipy) (1.26.1)
Downloading scipy-1.15.1-cp312-cp312-macosx_10_13_x86_64.whl (41.5 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 41.5/41.5 MB 6.8 MB/s eta 0:00:00
Installing collected packages: scipy
Successfully installed scipy-1.15.1
admins-MacBook-Pro:python admin$
```

Then type: `pip3 install pyserial`

```
admins-MacBook-Pro:~ admin$ pip3 install pyserial
Collecting pyserial
  Using cached pyserial-3.5-py2.py3-none-any.whl.metadata (1.6 kB)
Using cached pyserial-3.5-py2.py3-none-any.whl (90 kB)
Installing collected packages: pyserial
  WARNING: The scripts pyserial-miniterm and pyserial-ports are installed in '/Library/Frameworks/Python.framework/Versions/3.12/bin' which is not on PATH.
  Consider adding this directory to PATH or, if you prefer to suppress this warning, use --no-warn-script-location.
Successfully installed pyserial-3.5
admins-MacBook-Pro:~ admin$
```


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Now we can install the controller itself. The release package comes either as a compressed file called `SWMilliBox.zip` or as an already uncompressed directory on a USB flash drive. Copy the contents over to your home directory `~/SWMilliBox`.

From the terminal window, type:
cp -r /Volumes/<USB drivename>/SWMilliBox ~
Note that the software will be placed in your home directory at `/Users/<username>/SWMilliBox.`
As shown below:

```
admins-MacBook-Pro:~ admin$ pwd
/Users/admin
admins-MacBook-Pro:~ admin$ cp -r /Volumes/SONY_16GU/SWMilliBox .
admins-MacBook-Pro:~ admin$ ls -al
total 120
drwxr-xr-x+ 22 admin  staff    704 Apr 13 22:21 .
drwxr-xr-x   5 root   admin    160 May  8  2019 ..
-r--------   1 admin  staff      7 May  8  2019 .CFUserTextEncoding
-rw-r--r--@  1 admin  staff  14340 Apr 13 22:06 .DS_Store
drwx------   4 admin  staff    128 Apr 13 22:09 .Trash
-rw-------   1 admin  staff   5976 Apr 13 22:07 .bash_history
-rw-r--r--   1 admin  staff      1 May  8  2019 .bash_profile
drwx------   9 admin  staff    288 Apr 13 22:07 .bash_sessions
drwxr-xr-x   4 admin  staff    128 May  8  2019 .idlerc
-rw-------   1 admin  staff     52 May  8  2019 .lesshst
drwxr-xr-x   5 admin  staff    160 Apr 13 01:26 .matplotlib
-rw-------   1 admin  staff    105 Apr 13 02:39 .python_history
-rw-------   1 admin  staff  16466 Apr 13 21:03 .viminfo
drwx------+  5 admin  staff    160 May  9  2019 Desktop
drwx------+  9 admin  staff    288 Apr 13 22:20 Documents
drwx------+  4 admin  staff    128 Apr 13 22:09 Downloads
drwx------@ 56 admin  staff   1792 May  8  2019 Library
drwx------+  3 admin  staff     96 May  8  2019 Movies
drwx------+  3 admin  staff     96 May  8  2019 Music
drwx------+  3 admin  staff     96 May  8  2019 Pictures
drwxr-xr-x+  4 admin  staff    128 May  8  2019 Public
drwxr-xr-x   6 admin  staff    192 Apr 13 22:21 SWMilliBox
admins-MacBook-Pro:~ admin$
```


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Browse to the mbx code directory by doing:
`cd ~/SWMilliBox/MBX/python`

At this time, power on the positioner and attach the U2D2 to a USB port on the Mac machine.

Determine whether the U2D2 is connected: `ls -al /dev/cu.*`

```
admins-MacBook-Pro:python admin$ ls -al /dev/cu.*
 crw-rw-rw-  1 root  wheel   18,   1 Jan 28 14:03 /dev/cu.Bluetooth-Incoming-Port
 crw-rw-rw-  1 root  wheel   18,   3 Jan 28 14:28 /dev/cu.usbserial-FT951EHC
```

Look for a device named “usbserial”. In our case the COM port connected to the gimbal is called `/dev/cu.usbserial-FT951EHC`
If it isn’t there, then the U2D2 has not connected. Wait a few moments, then enter the command again. Otherwise, there may be an issue between the computer and the U2D2.

Now, from a shell in the MBX directory issue the command `python3 mbx.py`
Currently, we see that the MilliBox controller is running its initialization and bringing the controller user menu like below.

```
admins-MacBook-Pro:python admin$ python3 mbx.py

MilliBox Software Release: 24.0
Python Version: 3.12.0 (v3.12.0:0fb18b02c8, Oct  2 2023, 09:45:56) [Clang 13.0.0 (clang-
1300.0.29.30)]

**** Found no previous connection to a gimbal. Running autoscan. ****


Checking all comports...


Port /dev/cu.Bluetooth-Incoming-Port is not a FT232H (U2D2)

Port /dev/cu.usbserial-FT7W91OA is a FT232H (U2D2)
Checking all supported baudrates...

Scanning at baudrate 1000000 bps
==> Port /dev/cu.usbserial-FT7W91OA is not a GIM on baudrate 1000000, error 26

Scanning at baudrate 57600 bps
Succeeded to open the port (/dev/cu.usbserial-FT7W91OA)!
Succeeded to set the baudrate to 57600!
PH42_020 identified at ID 1
XH540_V270 identified at ID 2
XH540_V270 identified at ID 3
==> Port /dev/cu.usbserial-FT7W91OA is a GIM on baudrate 57600

Done scanning all comports...

**** CHOOSING PORT /dev/cu.usbserial-FT7W91OA AT BAUDRATE 57600 ****

Connecting to /dev/cu.usbserial-FT7W91OA at baudrate 57600
device /dev/cu.usbserial-FT7W91OA  port /dev/cu.usbserial-FT7W91OA
Succeeded to open the port (/dev/cu.usbserial-FT7W91OA)!
Succeeded to set the baudrate to 57600!
===== Gimbal type CHECK =====
====> Motor3 (R) motor identified
```


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```
====> GIM03/04 identified
====> Motor2 (V) motor identified
====> PH42 Base identified
===== motor configuration CHECK =====
torque for motor 1 is already disabled
torque for motor 2 is already disabled
torque for motor 3 is already disabled
flash access set
operating mode H = 4
**** Operating mode is OK ****
operating mode V = 4
**** Operating mode is OK ****
operating mode R = 4
**** Operating mode is OK ****
drive mode R = 3
reverse motor drive mode is OK
H moving threshold OK
V moving threshold OK
=== setting motors dynamic parameters ===
torque now enabled for motor 1
torque now enabled for motor 2
torque now enabled for motor 3
ram access enabled
H PID configuration set
V PID configuration set
verifying all settings
H position D gain : 0 = 0
H position P gain : 3000 = 3000
H position I gain : 3000 = 3000
H FF1 gain : 0 = 0
V position D gain : 0 = 0
V position P gain : 1000 = 1000
V position I gain : 3000 = 3000
V FF1 gain : 0 = 0
BOOT UP MOTOR POSITION CHECK before re-alignement
Current position for motor 1  is =  0.0 degree, Position is : 0 steps,  Offset is : 13756
Current position for motor 2  is =  91.494 degree, Position is : 3089 steps,  Offset is : 949
*************************************************************
motor=1   led=1   offset= 13756   goalpos=     0   drmode=0
motor=2   led=1   offset=   949   goalpos=  3089   drmode=0
*************************************************************
firmware version of motor H is OKAY
motor=1   led=1   offset= 13756   goalpos=     0   drmode=0
power cycle not detected --> no alignment needed
firmware version of motor V is OKAY
motor=2   led=1   offset=   949   goalpos=  3089   drmode=0
power cycle not detected --> no alignment needed
*************************************************************
motor=1   led=1   offset= 13756   goalpos=     0   drmode=0
motor=2   led=1   offset=   949   goalpos=  3089   drmode=0
*************************************************************
*** set_motor_motion_default ***
H model is = 2000
V model is = 1140
****** GIM motion settings ******
    gim_type = 1
  num_motors = 3
    accuracy = HIGH
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500, 'anglelim': [-180, 180]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10, 'anglelim': [-180, 180]}
Device connected
GIM TYPE = HV
Found 3 motor(s)
going to zero position
++++++++++++++++ MilliBox Gimbal is ready  ++++++++++++++

H model is = 2000
V model is = 1140
GIM motion parameter not defined! Using default values
```


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```
****** GIM motion settings ******
    gim_type = 1
  num_motors = 3
    accuracy = HIGH
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500, 'anglelim': [-180, 180]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10, 'anglelim': [-180, 180]}
mbx.cfg saved to file


******* Measurement Mode = NONE *******

**************************************************
*
*       Mode: NONE
* Instrument: ['SIMULATION']
*  Corr File: ---
*  Save Corr: ---
*     Zigzag: True
*   Position: (0.00, 0.00)
*
************* MAIN MENU *************************
************ USE KEYBOARD ************************
* Press <ESC> or <q> to close ports and quit!
__________ MOVEMENT/ALIGNMENT __________
* use <arrow keys> or <ijkl> to adjust H and V angles
* use <a> to reduce step size for finer alignment resolution
* use <s> to increase step size for coarser alignment resolution
* press <ZERO> key to store H0 V0 position
* press <h> to go home to last saved H0 V0 home position
* press <m> to open the direct move travel menu
* press <b> to start electronic beam alignment
* press <.> to print current position
_________ GIM MOTION SETTINGS __________
* press <g> to display GIM motion parameters
* press <v> to open the velocity setting menu
* press <r> to open the accel limit setting menu
* press <t> to open the angle limit setting menu
* press <e> to toggle accuracy setting
* press <w> to reset GIM parameters to default
__________ MEASUREMENT SETUP ___________
* press <y> to set measurement mode (VNA/SG+SA/SA/NONE) and set equipment VISA address
* press <x> to get current power measurement
* press <n> to save current power measurement to file
* press <o> to display correction factor menu
* press <f> to force instrument re-initialization
__________ MEASUREMENT SWEEPS __________
* press <d> to start default plot H -90 90 V -90 90 Step 15deg
* press <c> to start accuracy position check menu
* press <z> to toggle zigzag movement mode for 2D sweeps
* press <1> to start a 1-D sweep
* press <2> to start a 2-D sweep
* press <3> to start a 1-D sweep in E-plane and H-plane
_________ DATA POST-PROCESSING __________
* press <p> to plot from previous measurement
* press </> to display post-processing menu
___________ SPECIAL SETTINGS ___________
* press <:> to change motor baudrate configuration
* press <+> to reset offset for home position
* press <\> to toggle test menu
*********************************************************
```


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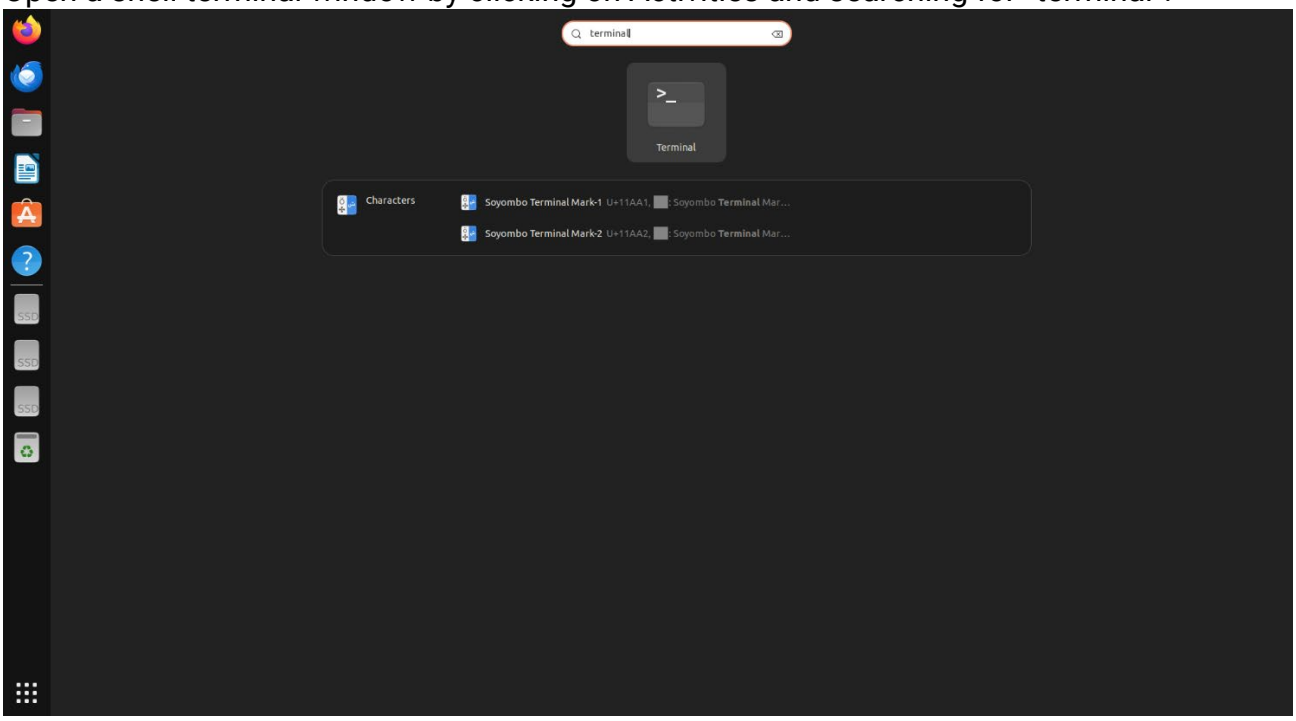
Notes about MacOS operation:

Unlike with Windows where keyboard keystrokes can take effect immediately, with MacOS, keyboard inputs must be followed by the enter key to be input into the MilliBox controller.
MacOS UART maximum baud rate is 57.6kbps but most MilliBox positioner's default factory baudrate is set at 1Mbps. For this you need your positioner to be configured for 57.6kbps, it can be done using R+Manager or using the MilliBox controller from a Windows-based PC and using the command ':' to do so.

Linux installation.

If you want to use the MilliBox controller on a Linux operating system, follow these steps:
Note that directions may vary depending on which Linux distribution you're using. These directions were tested on Ubuntu 22.04.5.

Open a shell terminal window by clicking on Activities and searching for "terminal":



On Linux, users don't have access to serial ports by default, which makes them unable to communicate with the MilliBox controller. To solve this, you need to enter `id -un` to get your user id and then enter `sudo usermod -aG dialout <user id>` which will add your user account to the dialout group, giving you serial port access.

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```
millibox@millibox-ThinkPad-X1-Carbon-3rd:~$ id -un
millibox
millibox@millibox-ThinkPad-X1-Carbon-3rd:~$ sudo usermod -aG dialout millibox
```

In the terminal window, type: `sudo apt install python3` to ensure that python is installed.

```
millibox@millibox-ThinkPad-X1-Carbon-3rd:~$ sudo apt install python3
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
python3 is already the newest version (3.10.6-1~22.04.1).
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.
```

At this point we can add our necessary python modules and dependencies.
Type: `pip3 install matplotlib` in the terminal

```
millibox@millibox-ThinkPad-X1-Carbon-3rd:~$ pip3 install matplotlib
Defaulting to user installation because normal site-packages is not writeable
Collecting matplotlib
  Downloading matplotlib-3.10.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (11 kB)
Collecting contourpy>=1.0.1 (from matplotlib)
  Downloading contourpy-1.3.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (5.4 kB)
Collecting cycler>=0.10 (from matplotlib)
  Downloading cycler-0.12.1-py3-none-any.whl.metadata (3.8 kB)
Collecting fonttools>=4.22.0 (from matplotlib)
  Downloading fonttools-4.55.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (165 kB)
Collecting kiwisolver>=1.3.1 (from matplotlib)
  Downloading kiwisolver-1.4.8-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x86_64.whl.metadata (6.2 kB)
Collecting numpy>=1.23 (from matplotlib)
  Downloading numpy-2.2.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (62 kB)
Collecting packaging>=20.0 (from matplotlib)
  Downloading packaging-24.2-py3-none-any.whl.metadata (3.2 kB)
Requirement already satisfied: pillow>=8 in /usr/lib/python3/dist-packages (from matplotlib) (9.0.1)
Requirement already satisfied: pyparsing>=2.3.1 in /usr/lib/python3/dist-packages (from matplotlib) (2.4.7)
Requirement already satisfied: python-dateutil>=2.7 in /usr/lib/python3/dist-packages (from matplotlib) (2.8.1)
Downloading matplotlib-3.10.0-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (8.6 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 8.6/8.6 MB 7.8 MB/s eta 0:00:00
Downloading contourpy-1.3.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (324 kB)
Downloading cycler-0.12.1-py3-none-any.whl (8.3 kB)
Downloading fonttools-4.55.3-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (4.6 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 4.6/4.6 MB 8.4 MB/s eta 0:00:00
Downloading kiwisolver-1.4.8-cp310-cp310-manylinux_2_12_x86_64.manylinux2010_x86_64.whl (1.6 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 1.6/1.6 MB 8.7 MB/s eta 0:00:00
Downloading numpy-2.2.2-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (16.4 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 16.4/16.4 MB 8.3 MB/s eta 0:00:00
Downloading packaging-24.2-py3-none-any.whl (65 kB)
Installing collected packages: packaging, numpy, kiwisolver, fonttools, cycler, contourpy, matplotlib
Successfully installed contourpy-1.3.1 cycler-0.12.1 fonttools-4.55.3 kiwisolver-1.4.8 matplotlib-3.10.0 numpy-2.2
.2 packaging-24.2
```


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When matplotlib library is installed

Type: `pip3 install pyvisa`

```
millibox@millibox-ThinkPad-X1-Carbon-3rd:~$ pip3 install pyvisa
Defaulting to user installation because normal site-packages is not writeable
Collecting pyvisa
  Downloading PyVISA-1.14.1-py3-none-any.whl.metadata (7.1 kB)
Collecting typing-extensions (from pyvisa)
  Downloading typing_extensions-4.12.2-py3-none-any.whl.metadata (3.0 kB)
Downloading PyVISA-1.14.1-py3-none-any.whl (176 kB)
Downloading typing_extensions-4.12.2-py3-none-any.whl (37 kB)
Installing collected packages: typing-extensions, pyvisa
Successfully installed pyvisa-1.14.1 typing-extensions-4.12.2
```

Then type: `pip3 install pyvisa-py`

```
millibox@millibox-ThinkPad-X1-Carbon-3rd:~/SWMilliBox$ pip3 install pyvisa-py
Defaulting to user installation because normal site-packages is not writeable
Collecting pyvisa-py
  Using cached PyVISA_py-0.7.2-py3-none-any.whl.metadata (6.6 kB)
Requirement already satisfied: pyvisa>=1.13.0 in /home/millibox/.local/lib/python3.10/site-packages (from pyvisa-py) (1.14.1)
Requirement already satisfied: typing-extensions in /home/millibox/.local/lib/python3.10/site-packages (from pyvisa-py) (4.12.2)
Using cached PyVISA_py-0.7.2-py3-none-any.whl (75 kB)
Installing collected packages: pyvisa-py
Successfully installed pyvisa-py-0.7.2
```

Then type: `pip3 install scipy`

```
millibox@millibox-ThinkPad-X1-Carbon-3rd:~$ pip3 install scipy
Defaulting to user installation because normal site-packages is not writeable
Collecting scipy
  Downloading scipy-1.15.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (61 kB)
Requirement already satisfied: numpy<2.5,>=1.23.5 in ./.local/lib/python3.10/site-packages (from scipy) (2.2.2)
Downloading scipy-1.15.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (40.6 MB)
   ━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━ 40.6/40.6 MB 8.5 MB/s eta 0:00:00
Installing collected packages: scipy
Successfully installed scipy-1.15.1
```

Then type: `pip3 install pyserial`

```
millibox@millibox-ThinkPad-X1-Carbon-3rd:~$ pip3 install pyserial
Defaulting to user installation because normal site-packages is not writeable
Collecting pyserial
  Using cached pyserial-3.5-py2.py3-none-any.whl.metadata (1.6 kB)
Using cached pyserial-3.5-py2.py3-none-any.whl (90 kB)
Installing collected packages: pyserial
Successfully installed pyserial-3.5
```


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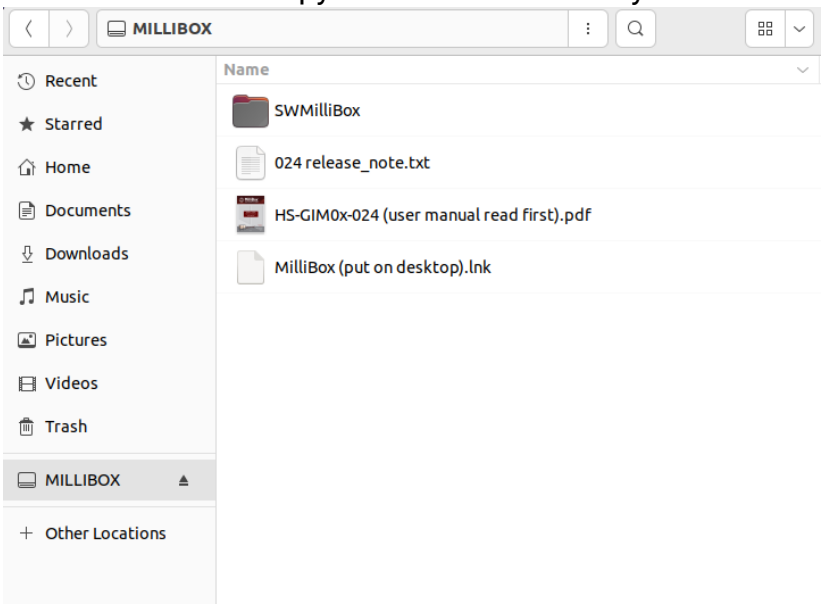
Now we can install the controller itself. The release package comes either as a compressed file called `SWMilliBox.zip` or as an already uncompressed directory on a USB flash drive. Copy the contents over to your home directory `~/SWMilliBox`.



From the terminal window, type:
cp -r /media/<username>/<USB drivename>/SWMilliBox ~
Note that the software will be placed in your home directory at
`/Users/<username>/SWMilliBox`

Browse to the mbx code directory by doing:
`cd ~/SWMilliBox/MBX/python`

Then power on the positioner and attach the USB dongle to a USB port on the Linux machine.

Now issue the command `python3 mbx.py` in that terminal window.
The first time you run it you should see something like this:

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```
~/SWMilliBox/MBX/python$ python3 mbx.py

MilliBox Software Release: 24.0
Python Version: 3.10.12 (main, Nov  6 2024, 20:22:13) [GCC
11.4.0]

**** Found no previous connection to a gimbal. Running autoscan.
****


Checking all comports...


Port /dev/ttyS0 is not a FT232H (U2D2)


Port /dev/ttyS1 is not a FT232H (U2D2)


Port /dev/ttyS2 is not a FT232H (U2D2)


Port /dev/ttyS3 is not a FT232H (U2D2)


…


Port /dev/ttyS30 is not a FT232H (U2D2)


Port /dev/ttyS31 is not a FT232H (U2D2)

Port /dev/ttyUSB0 is a FT232H (U2D2)
Checking all supported baudrates...

Scanning at baudrate 1000000 bps
Succeeded to open the port (/dev/ttyUSB0)!
Succeeded to set the baudrate to 1000000!
PH42_020 identified at ID 1
XH540_V270 identified at ID 2
XH540_V270 identified at ID 3
==> Port /dev/ttyUSB0 is a GIM on baudrate 1000000

Scanning at baudrate 57600 bps
```


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```
Succeeded to open the port (/dev/ttyUSB0)!
Succeeded to set the baudrate to 57600!
==> Port /dev/ttyUSB0 is not a GIM on baudrate 57600, error 25

Done scanning all comports...

**** CHOOSING PORT /dev/ttyUSB0 AT BAUDRATE 1000000 ****

Connecting to /dev/ttyUSB0 at baudrate 1000000
device /dev/ttyUSB0  port /dev/ttyUSB0
Succeeded to open the port (/dev/ttyUSB0)!
Succeeded to set the baudrate to 1000000!
===== Gimbal type CHECK =====
====> Motor3 (R) motor identified
====> GIM03/04 identified
====> Motor2 (V) motor identified
====> PH42 Base identified
===== motor configuration CHECK =====
torque for motor 1 is already disabled
torque for motor 2 is already disabled
torque for motor 3 is already disabled
flash access set
operating mode H = 4
**** Operating mode is OK ****
operating mode V = 4
**** Operating mode is OK ****
operating mode R = 4
**** Operating mode is OK ****
drive mode R = 3
reverse motor drive mode is OK
H moving threshold OK
V moving threshold OK
=== setting motors dynamic parameters ===
torque now enabled for motor 1
torque now enabled for motor 2
torque now enabled for motor 3
ram access enabled
H PID configuration set
V PID configuration set
verifying all settings
H position D gain : 0 = 0
H position P gain : 3000 = 3000
H position I gain : 3000 = 3000
H FF1 gain : 0 = 0
V position D gain : 0 = 0
V position P gain : 1000 = 1000
```


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```
V position I gain : 3000 = 3000
V FF1 gain : 0 = 0
BOOT UP MOTOR POSITION CHECK before re-alignement
Current position for motor 1  is =  0.0 degree, Position is : 0
steps,  Offset is : 13756
Current position for motor 2  is =  92.373 degree, Position is :
3099 steps,  Offset is : 949
************************************************************
motor=1   led=1   offset= 13756   goalpos=     0   drmode=0
motor=2   led=1   offset=   949   goalpos=  3098   drmode=0
************************************************************
firmware version of motor H is OKAY
motor=1   led=1   offset= 13756   goalpos=     0   drmode=0
power cycle not detected --> no alignment needed
firmware version of motor V is OKAY
motor=2   led=1   offset=   949   goalpos=  3098   drmode=0
power cycle not detected --> no alignment needed
************************************************************
motor=1   led=1   offset= 13756   goalpos=     0   drmode=0
motor=2   led=1   offset=   949   goalpos=  3098   drmode=0
************************************************************
*** set_motor_motion_default ***
H model is = 2000
V model is = 1140
****** GIM motion settings ******
    gim_type = 1
  num_motors = 3
    accuracy = HIGH
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500,
'anglelim': [-180, 180]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10,
'anglelim': [-180, 180]}
Device connected
GIM TYPE = HV
Found 3 motor(s)
going to zero position
+++++++++++++++ MilliBox Gimbal is ready  +++++++++++++++

H model is = 2000
V model is = 1140
GIM motion parameter not defined! Using default values
****** GIM motion settings ******
    gim_type = 1
  num_motors = 3
    accuracy = HIGH
```


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```
           1 = {'model': 2000, 'vel': 14.6, 'accel': 2500,
'anglelim': [-180, 180]}
           2 = {'model': 1140, 'vel': 234.267, 'accel': 10,
'anglelim': [-180, 180]}
mbx.cfg saved to file


******* Measurement Mode = NONE *******

**************************************************
*
*       Mode: NONE
* Instrument: ['SIMULATION']
*  Corr File: ---
*  Save Corr: ---
*     Zigzag: True
*   Position: (0.00, 0.09)
*
************* MAIN MENU *************************
************ USE KEYBOARD ************************
* Press <ESC> or <q> to close ports and quit!
__________ MOVEMENT/ALIGNMENT __________
* use <arrow keys> or <ijkl> to adjust H and V angles
* use <a> to reduce step size for finer alignment resolution
* use <s> to increase step size for coarser alignment resolution
* press <ZERO> key to store H0 V0 position
* press <h> to go home to last saved H0 V0 home position
* press <m> to open the direct move travel menu
* press <b> to start electronic beam alignment
* press <.> to print current position
_________ GIM MOTION SETTINGS __________
* press <g> to display GIM motion parameters
* press <v> to open the velocity setting menu
* press <r> to open the accel limit setting menu
* press <t> to open the angle limit setting menu
* press <e> to toggle accuracy setting
* press <w> to reset GIM parameters to default
__________ MEASUREMENT SETUP ___________
* press <y> to set measurement mode (VNA/SG+SA/SA/NONE) and set
equipment VISA address
* press <x> to get current power measurement
* press <n> to save current power measurement to file
* press <o> to display correction factor menu
* press <f> to force instrument re-initialization
__________ MEASUREMENT SWEEPS __________
* press <d> to start default plot H -90 90 V -90 90 Step 15deg
```


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```
* press <c> to start accuracy position check menu
* press <z> to toggle zigzag movement mode for 2D sweeps
* press <1> to start a 1-D sweep
* press <2> to start a 2-D sweep
* press <3> to start a 1-D sweep in E-plane and H-plane
_________ DATA POST-PROCESSING _________
* press <p> to plot from previous measurement
* press </> to display post-processing menu
___________ SPECIAL SETTINGS ___________
* press <:> to change motor baudrate configuration
* press <+> to reset offset for home position
* press <\> to toggle test menu
*********************************************************
```

Note:
Unlike Windows where keyboard keystrokes can take effect immediately, Linux keyboard inputs must be followed by the enter key to be taken into account by the MilliBox controller.

When upgrading from an older version of MilliBox controller.

When upgrading from a version before 024 to a version 024 and later you need to install pyserial by typing: `py -3 -m pip install pyserial` into a terminal

Delete the MilliBox desktop icon
Rename the C:\SWMilliBox folder to C:\Old_SWMilliBox
Unzip the Millibox release such that the newer `SWMilliBox` folder Sits on C:\
Drag the new MilliBox Icon to the desktop.
Optionally if you want to keep your old captured data together you can move the folder from: C:\Old_SWMilliBox\MilliBox_plot_data\ into the new C:\SWMilliBox\MilliBox_plot_data\

When using multiple versions of Python on the same machine.

If your system has multiple versions of Python installed you can select which Python to run at instantiation of mbx.py with the following commands:
`>mbx.py` will run the default Python version.
`>py -2 mbx.py` will run mbx.py from the latest Python 2 installed on the machine
`>py -3 mbx.py` will run mbx.py from the latest Python 3 installed on the machine
`>py -3.12 mbx.py` will run mbx.py from Python 3.12 for example

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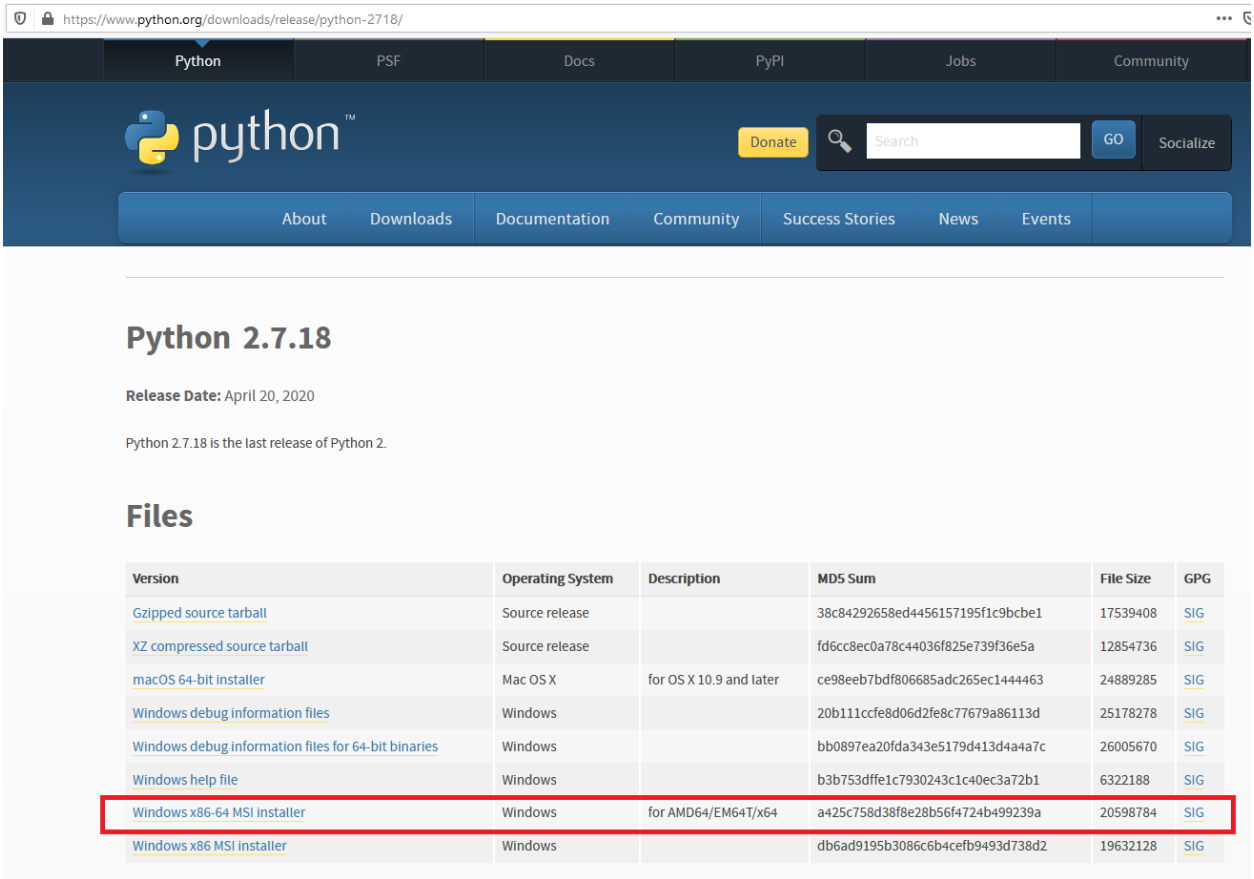
Python 2.7 on windows 10:

On the internet browse to:
https://www.python.org/downloads/release/python-2718/



Version	Operating System	Description	MD5 Sum	File Size	GPG
Gzipped source tarball	Source release		38c84292658ed4456157195f1c9bcbe1	17539408	SIG
XZ compressed source tarball	Source release		fd6cc8ec0a78c44036f825e739f36e5a	12854736	SIG
macOS 64-bit installer	Mac OS X	for OS X 10.9 and later	ce98eeb7bdf806685adc265ec1444463	24889285	SIG
Windows debug information files	Windows		20b111ccfe8d06d2fe8c77679a86113d	25178278	SIG
Windows debug information files for 64-bit binaries	Windows		bb0897ea20fda343e5179d413d4a4a7c	26005670	SIG
Windows help file	Windows		b3b753dffe1c7930243c1c40ec3a72b1	6322188	SIG
Windows x86-64 MSI installer	Windows	for AMD64/EM64T/x64	a425c758d38f8e28b56f4724b499239a	20598784	SIG
Windows x86 MSI installer	Windows		db6ad9195b3086c6b4cefb9493d738d2	19632128	SIG

In the list, you should choose “Windows x86 64 MSI installer” if your machine is 64 bit
Or choose “Windows x86 MSI installer” only if your machine is truly 32bit.

☛ Note: nearly all machines are 64bits nowadays, but the default Python install is 32bit, make sure you have a 64bit Python version installation if your machine is 64bits. The Python version and the driver libraries must match together, so if your operating system is 64bits but Python install is x86 (which is default option), the 3D positioner driver library won’t work.

Download and install Python27 in `C:\` for all users

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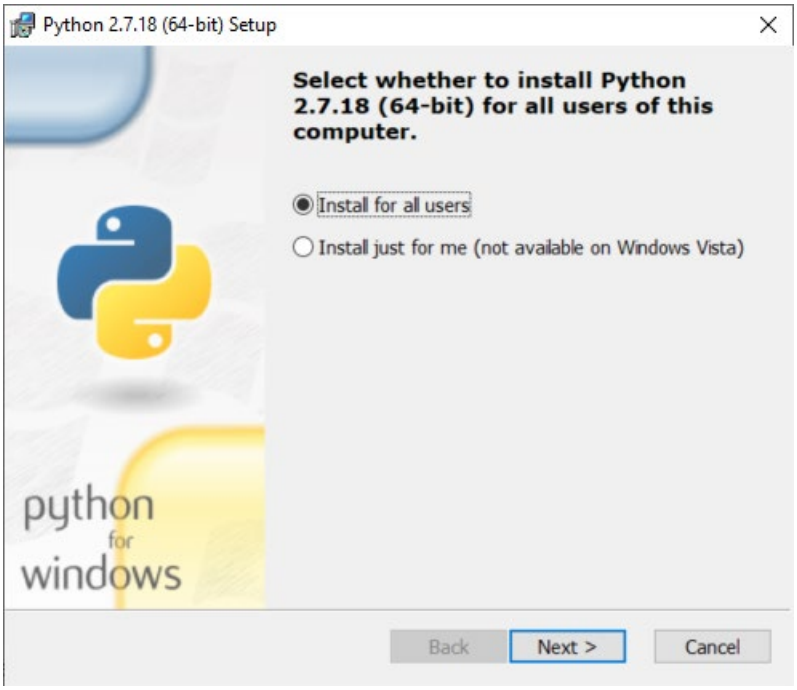
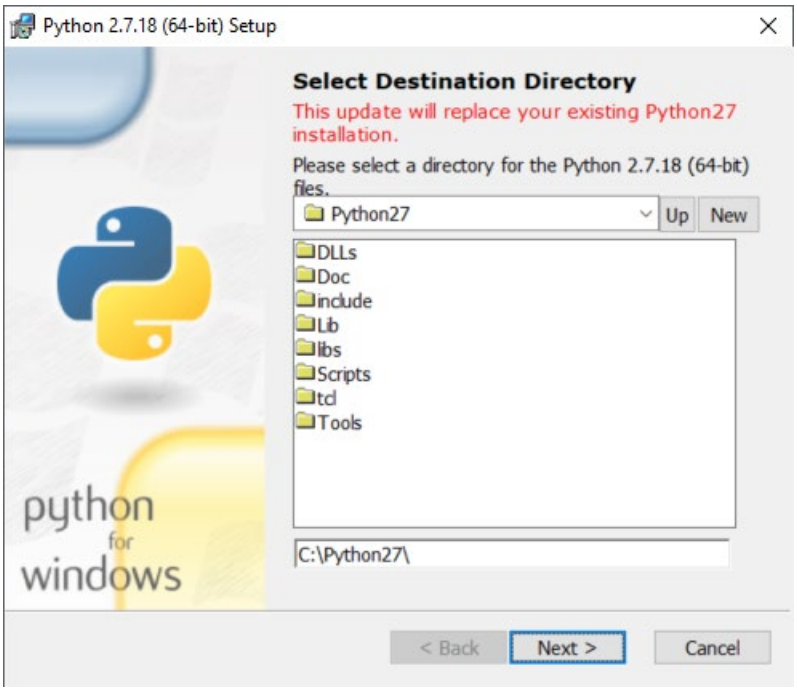


Press 'Next'



Press 'Next'

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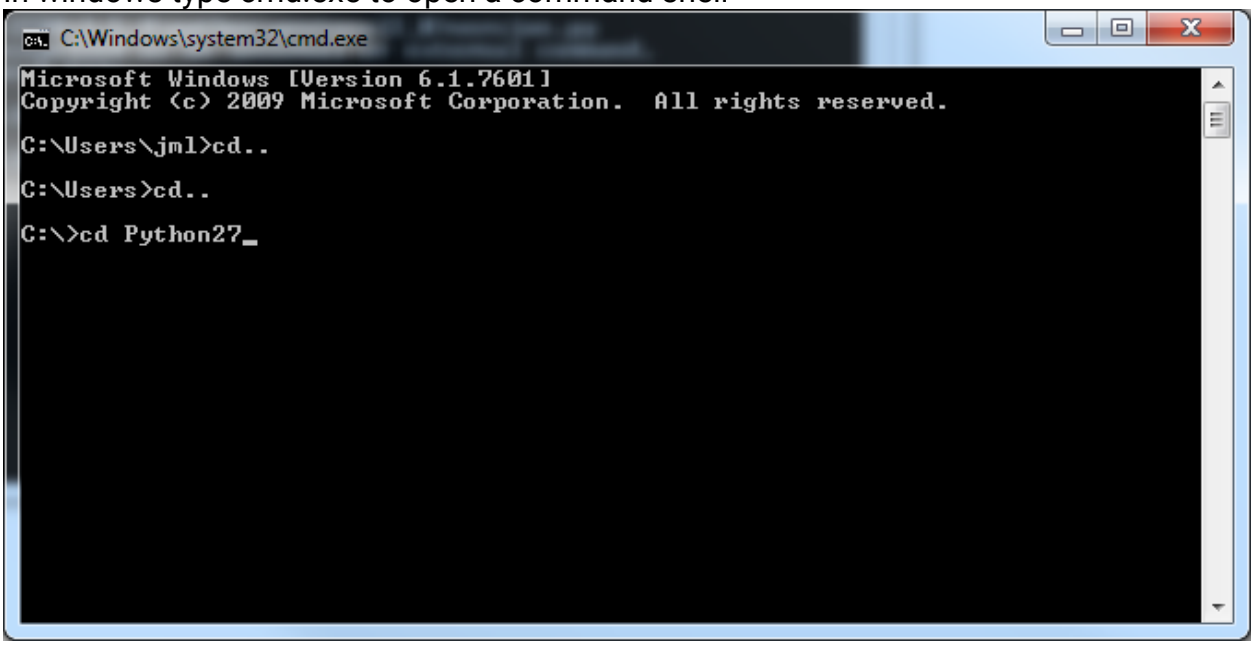
Install with default settings. Press 'Next'

Go through the installation process until completed.

In windows type cmd.exe to open a command shell



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Then in Python27 prompt type “python -m pip install pip --upgrade pip”

```
C:\Windows\system32\cmd.exe
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\jml>cd..

C:\Users>cd..

C:\>cd Python27

C:\Python27>python -m pip install pip --upgrade pip
```

It will show the pip update progress like below

```
Collecting pip
  Downloading pip-9.0.3-py2.py3-none-any.whl (1.4MB)
    100% |[redacted]| 1.4MB 409kB/s
Installing collected packages: pip
  Found existing installation: pip 9.0.1
    Uninstalling pip-9.0.1:
      Successfully uninstalled pip-9.0.1
Successfully installed pip-9.0.3
```

Then type `cd scripts` like below

```
C:\Python27>cd scripts

C:\Python27\Scripts>_
```

In scripts prompt:

Type “python -m pip install matplotlib”

```
C:\Python27\Scripts>
C:\Python27\Scripts>pip install matplotlib
```


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```
Collecting matplotlib
  Downloading matplotlib-2.2.2-cp36-cp36m-win_amd64.whl (8.7MB)
    100% |                                        | 8.7MB 124kB/s
Collecting six>=1.10 (from matplotlib)
  Using cached six-1.11.0-py2.py3-none-any.whl
Collecting cycler>=0.10 (from matplotlib)
  Using cached cycler-0.10.0-py2.py3-none-any.whl
Collecting pytz (from matplotlib)
  Downloading pytz-2018.3-py2.py3-none-any.whl (509kB)
    100% |                                        | 512kB 1.5MB/s
Requirement already satisfied: numpy>=1.7.1 in c:\users\jml\appdata\local\progra
ms\python\python36\lib\site-packages (from matplotlib)
Collecting kiwisolver>=1.0.1 (from matplotlib)
  Downloading kiwisolver-1.0.1-cp36-none-win_amd64.whl (57kB)
    100% |                                        | 61kB 1.5MB/s
Collecting python-dateutil>=2.1 (from matplotlib)
  Downloading python_dateutil-2.7.2-py2.py3-none-any.whl (212kB)
    100% |                                        | 215kB 3.4MB/s
Collecting pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 (from matplotlib)
  Using cached pyparsing-2.2.0-py2.py3-none-any.whl
Requirement already satisfied: setuptools in c:\users\jml\appdata\local\programs
\python\python36\lib\site-packages (from kiwisolver>=1.0.1->matplotlib)
Installing collected packages: six, cycler, pytz, kiwisolver, python-dateutil, p
yparsing, matplotlib
Successfully installed cycler-0.10.0 kiwisolver-1.0.1 matplotlib-2.2.2 pyparsing
-2.2.0 python-dateutil-2.7.2 pytz-2018.3 six-1.11.0
```

Then type: “`python -m pip install pyvisa`” to install pyVISA module to control instruments.

```
C:\Python27\Scripts>pip install pyvisa
DEPRECATION: Python 2.7 will reach the end of its life on January 1st, 2020. Ple
ase upgrade your Python as Python 2.7 won't be maintained after that date. A fut
ure version of pip will drop support for Python 2.7. More details about Python 2
 support in pip, can be found at https://pip.pypa.io/en/latest/development/relea
se-process/#python-2-support
Collecting pyvisa
  Downloading https://files.pythonhosted.org/packages/51/d1/fc21b45228718cde06b3
3b08761a6a9aa859dfe51dfbf07e81e0f209e776/PyVISA-1.10.1.tar.gz (6.8MB)
     |UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU| 6.8MB 3.0MB/s
Collecting enum34
  Downloading https://files.pythonhosted.org/packages/c5/db/e56e6b4bbac7c4a06de1
c50de6fe1ef3810018ae11732a50f15f62c7d050/enum34-1.1.6-py2-none-any.whl
Installing collected packages: enum34, pyvisa
    Running setup.py install for pyvisa ... done
Successfully installed enum34-1.1.6 pyvisa-1.10.1
```

Type: “`python -m pip install pyvisa-py`” to install pyVISA-py for the VISA driver.

```
C:\Python27\Scripts>pip install pyvisa-py
DEPRECATION: Python 2.7 reached the end of its life on January 1st, 2020. Please upgrade your Python as Python 2.7 is no
 longer maintained. pip 21.0 will drop support for Python 2.7 in January 2021. More details about Python 2 support in pi
p can be found at https://pip.pypa.io/en/latest/development/release-process/#python-2-support pip 21.0 will remove suppo
rt for this functionality.
Collecting pyvisa-py
  Downloading PyVISA-py-0.4.1.tar.gz (5.9 MB)
     |UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU| 5.9 MB 2.7 MB/s
Requirement already satisfied: pyvisa<1.11,>=1.8 in c:\python27\lib\site-packages (from pyvisa-py) (1.10.1)
Requirement already satisfied: enum34 in c:\python27\lib\site-packages (from pyvisa<1.11,>=1.8->pyvisa-py) (1.1.10)
Using legacy 'setup.py install' for pyvisa-py, since package 'wheel' is not installed.
Installing collected packages: pyvisa-py
    Running setup.py install for pyvisa-py ... done
Successfully installed pyvisa-py-0.4.1

C:\Python27\Scripts>
```


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Type "`python -m pip install scipy`" to install Scientific Python ressources.

```
Collecting scipy
  Obtaining dependency information for scipy from https://files.pythonhosted.org/packages/81/d7/d2537d51efb692d0c411e642
67ba349e7668d40f5bc73cefe78ccd650dcd/scipy-1.11.3-cp311-cp311-win_amd64.whl.metadata
  Downloading scipy-1.11.3-cp311-cp311-win_amd64.whl.metadata (60 kB)
     ---------------------------------------- 60.4/60.4 kB 1.1 MB/s eta 0:00:00
Requirement already satisfied: numpy<1.28.0,>=1.21.6 in c:\users\jlaurent\appdata\local\packages\pythonsoftwarefoundatio
n.python.3.11_qbz5n2kfra8p0\localcache\local-packages\python311\site-packages (from scipy) (1.26.0)
Downloading scipy-1.11.3-cp311-cp311-win_amd64.whl (44.1 MB)
   ---------------------------------------- 44.1/44.1 MB 7.6 MB/s eta 0:00:00
Installing collected packages: scipy
Successfully installed scipy-1.11.3

C:\Windows\System32>
```

Python installation is now complete.

Using R+ Manager to access all GIM0x registers directly:

This functionality is to be used for debugging or advanced development. Changing some registers outside of mbx framework may render the 3D positioner inoperable.

Browse to:
C:\SWMilliBox\Utilities\R+ Manager 2.0
Open the executable `R+Manager.exe`
It is not necessary to update R+ Manager when prompted

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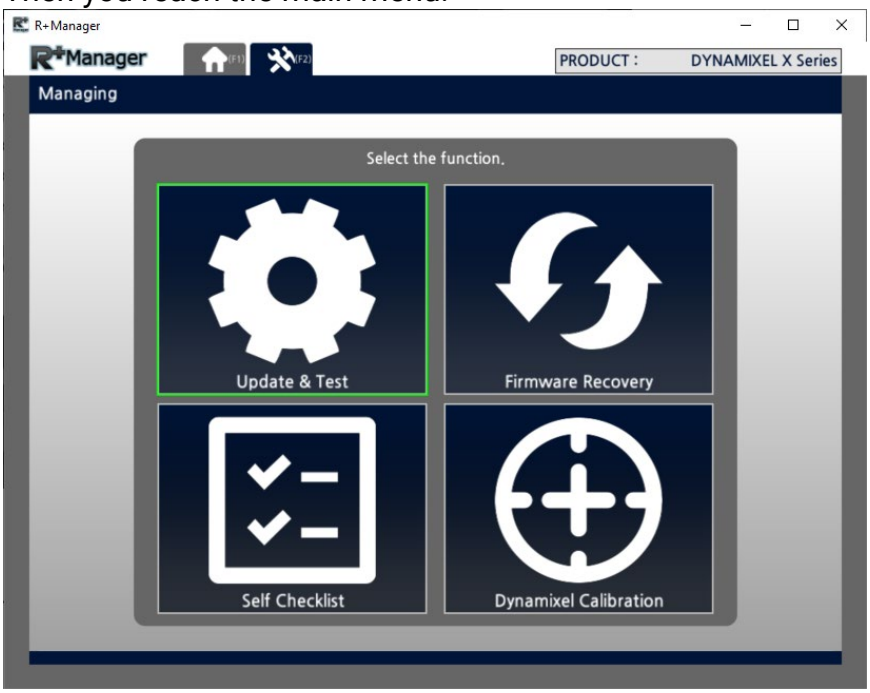
In the product list select DYNAMIXEL X and press O

Press O again
Then you reach the main menu:



Press: Update and Test Icon

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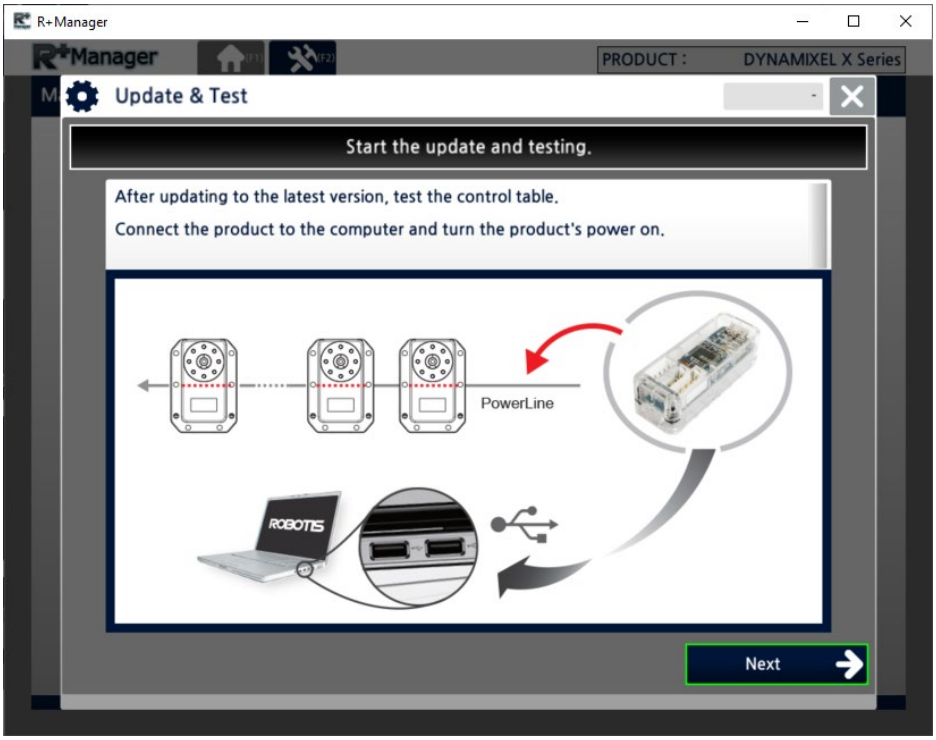
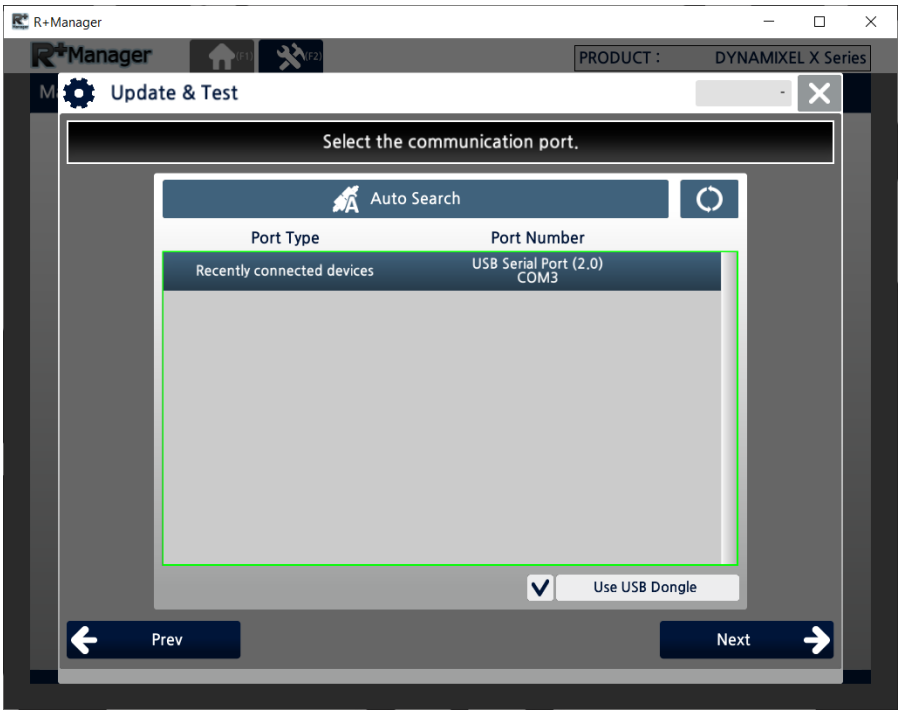


Press next in R+ Manager

It should look like this:



Select the USB Serial Port (2.0)

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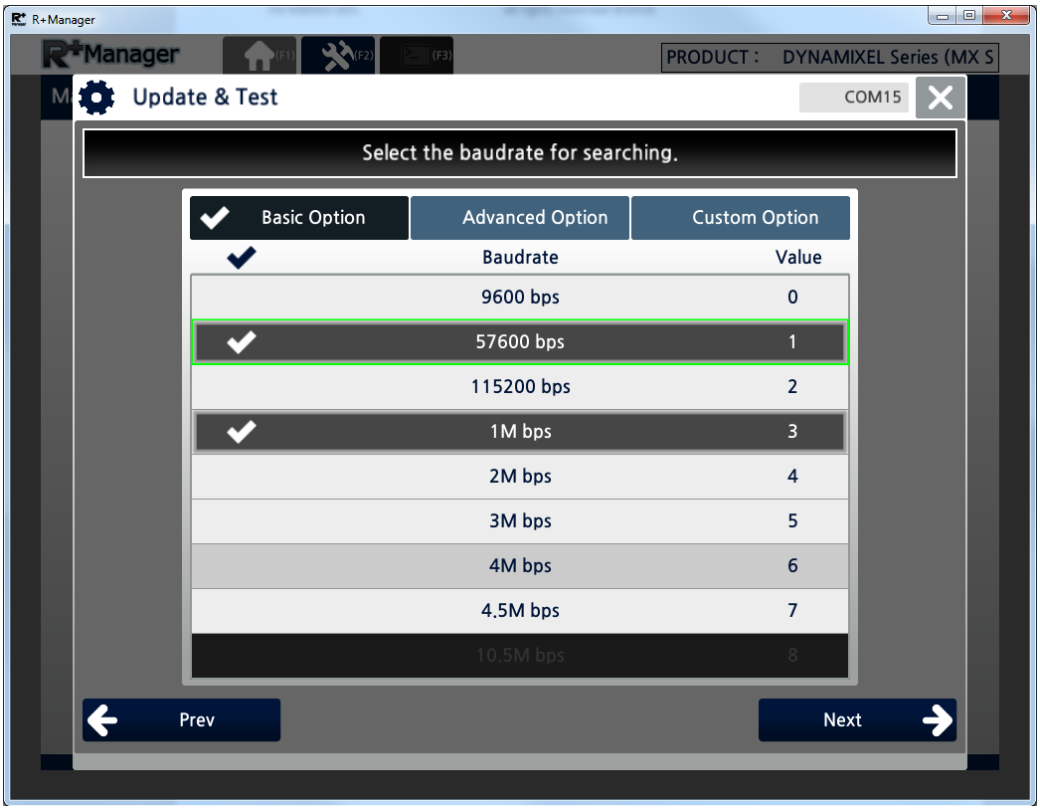
From the list select the COM port attached to your GIM0x



Make sure 1M bps is selected.
For a 3D positioner configured for MacOS: 57600 bps has to be selected.
Press next
It should progress and finish like this

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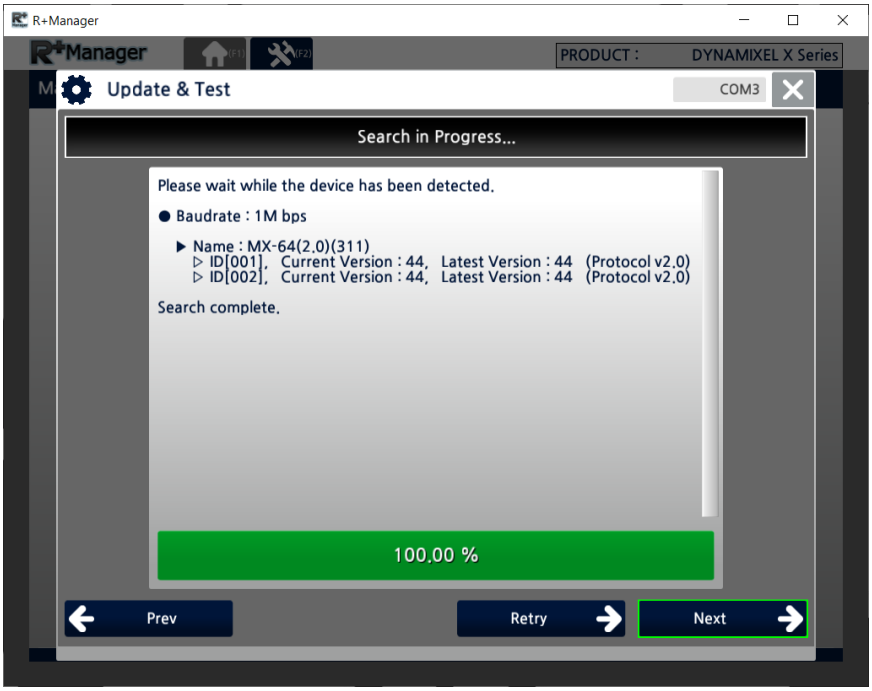

You should see exactly this screen showing the 2 motors of the 3D positioner connected with proper settings.
Note: for GIM03 you should see all 3 motors.

Note: if you are prompted to upgrade the motor firmware, you can do so now.

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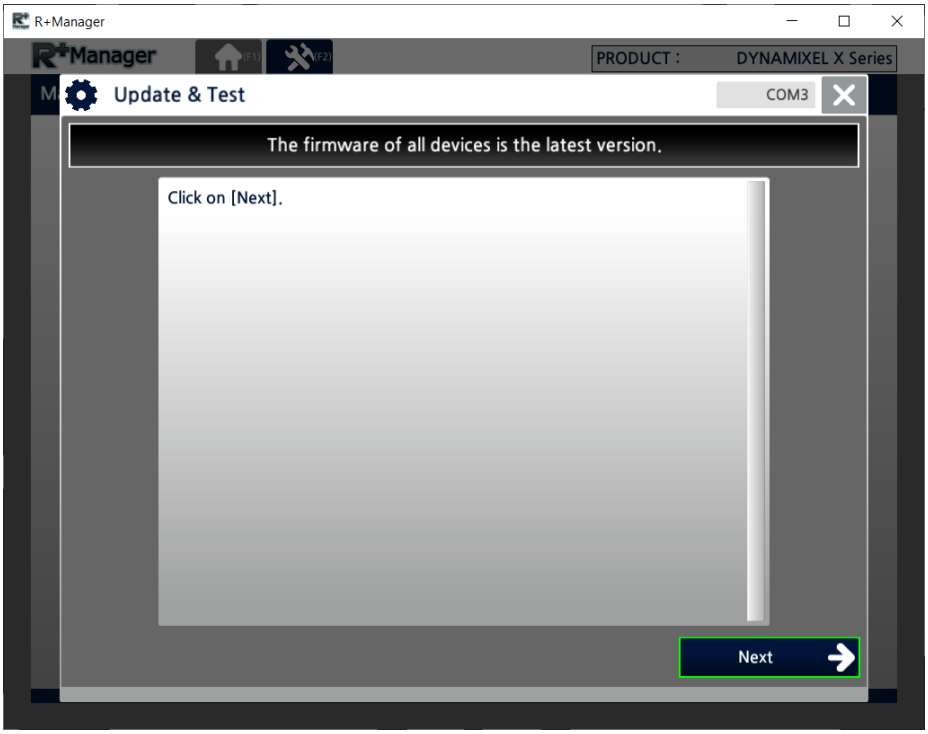
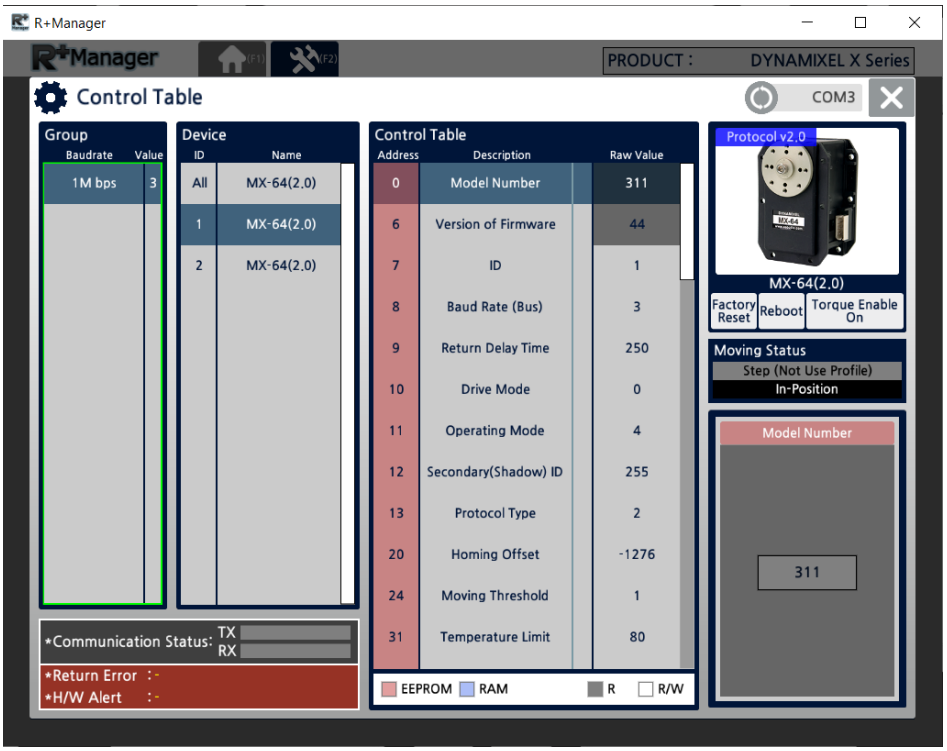


Click Next



At this point we can see the motor's registers for both motors.

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Note: Motor models vary as newer, more performant versions are introduced on the market.

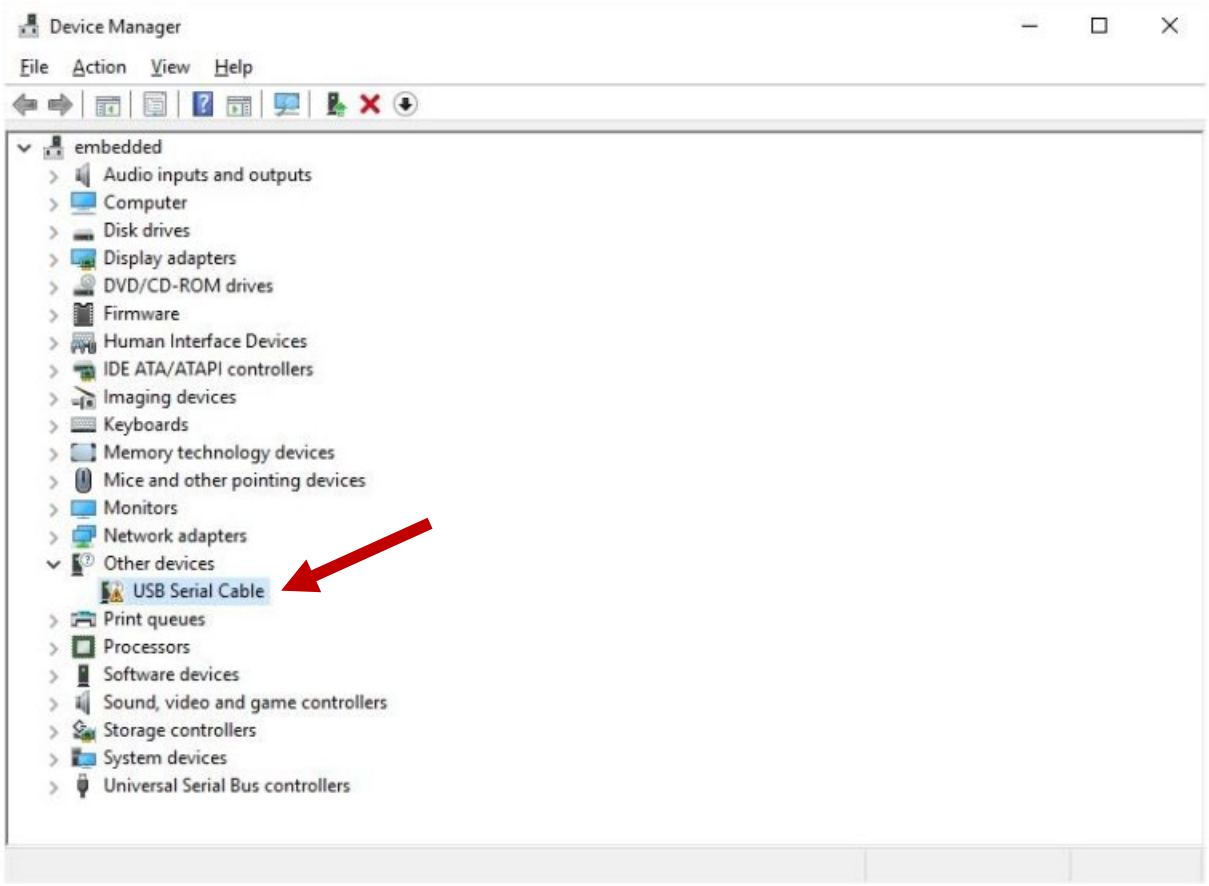
Be very careful not to do a factory reset of the motors or touch their ID. The motors are configured in MilliBox factory to operate in the positioners. MilliBox factory default is not compatible with Dynamixel factory default.

Be very careful not to modify registers which you don't know. Some can create serious damage to the positioner.

You can always contact MilliBox before making changes on those registers and in most cases, we can assist before you get yourself in trouble.

Manual driver installation:

If you do not have a network connection or have strict firewall rules it is possible that Windows can be blocked from installing the MilliBox drivers.
If this is your situation, open Windows Device Manager and find the device with unloaded driver like below



Note: it could also show as Cable Converter class.

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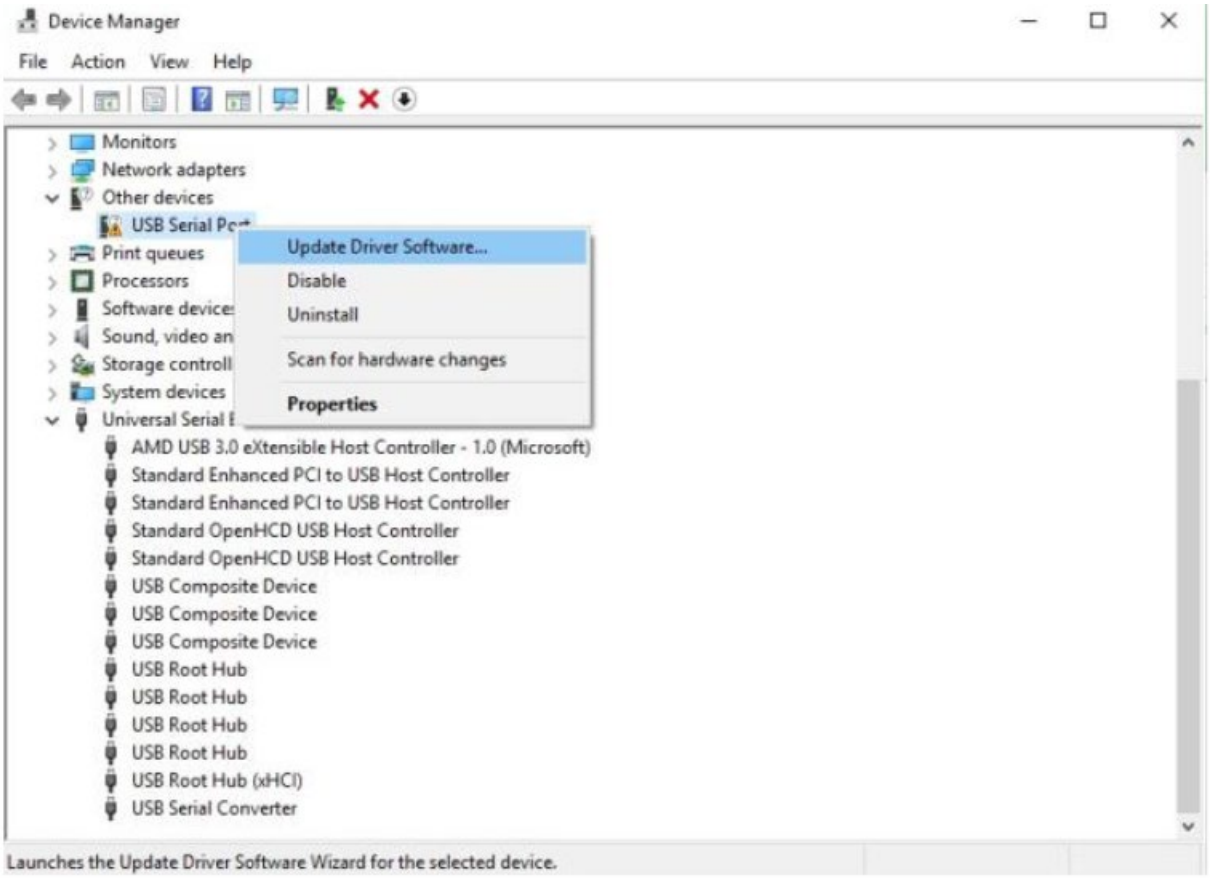
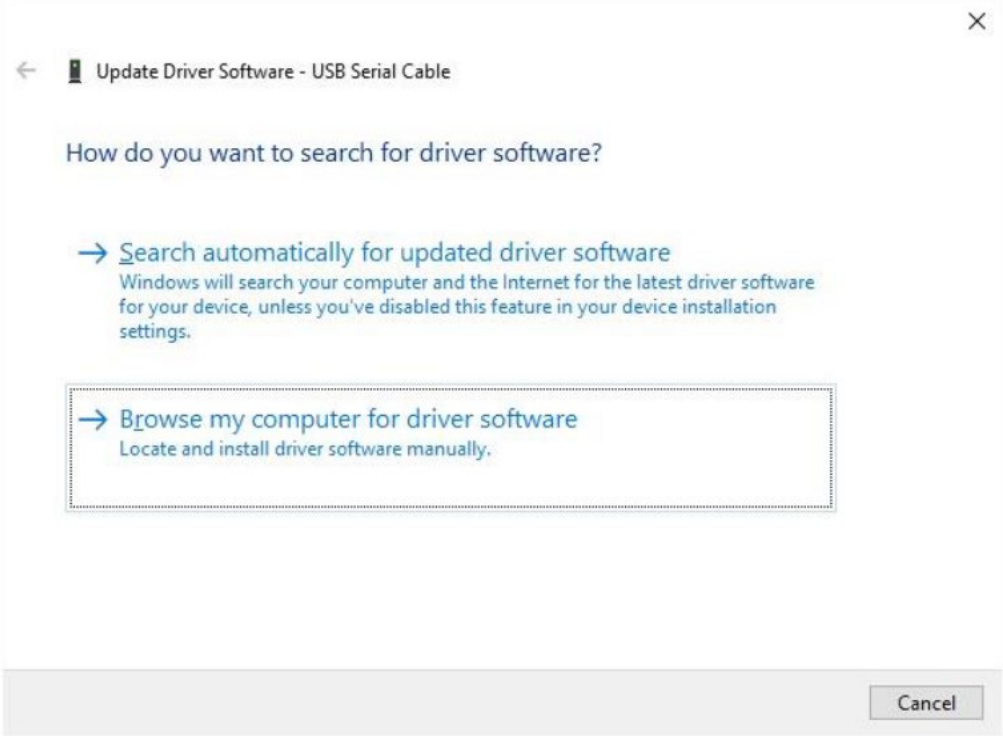


Right click on the device and select Update Driver Software.



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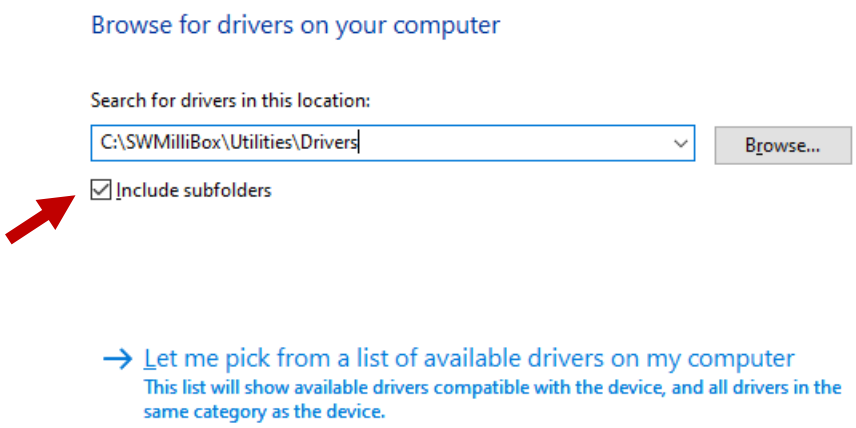
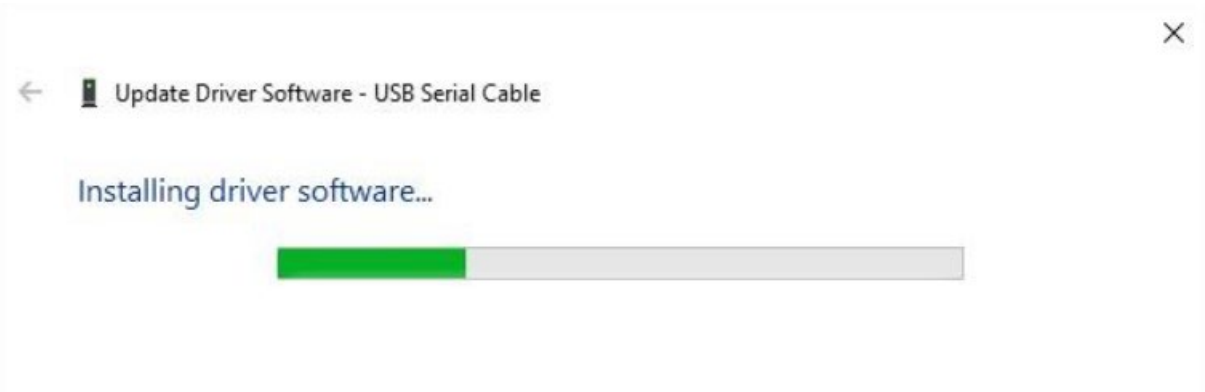
Select Browse my computer for driver software and make sure to check “Include subfolder” like shown below.
Set the search path to
C:\SWMilliBox\Utilities\Drivers



And click “Next”

A progress bar will show momentarily:



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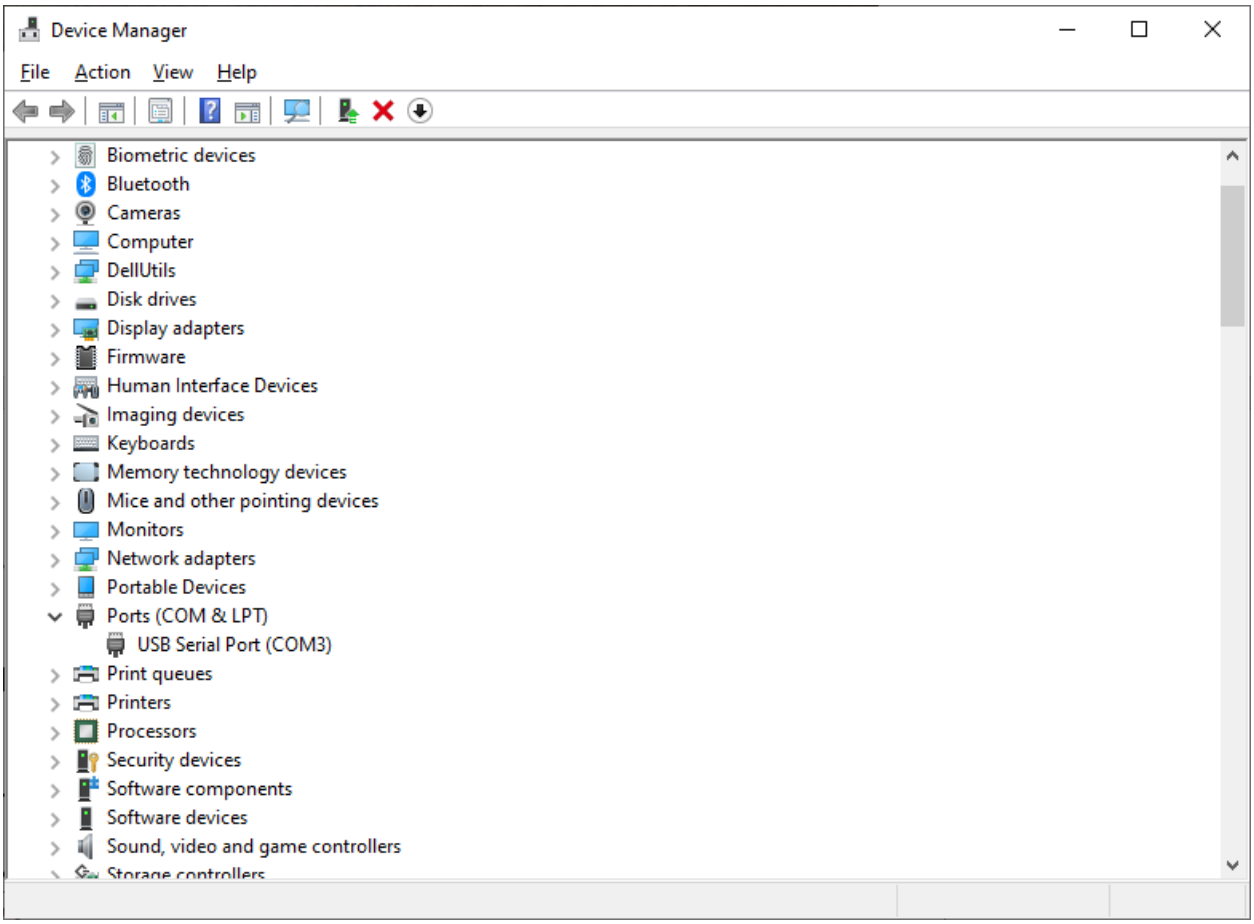
Then the completion screen will show:

At this time, you can return to the device manager and see that the com port is assigned correctly:



Note: you may have to repeat the process above twice:

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The first time to update the driver from “USB cable converter” to “USB serial cable” and from “USB serial cable” to “USB Serial Port(COMx)”

If this still did not work, the latest drivers can be downloaded here:
http://www.ftdichip.com/FTDrivers.htm

And the driver installation manual can be found here:
https://www.ftdichip.com/Support/Documents/InstallGuides/AN_396%20FTDI%20Drivers%20Installation%20Guide%20for%20Windows%2010.pdf

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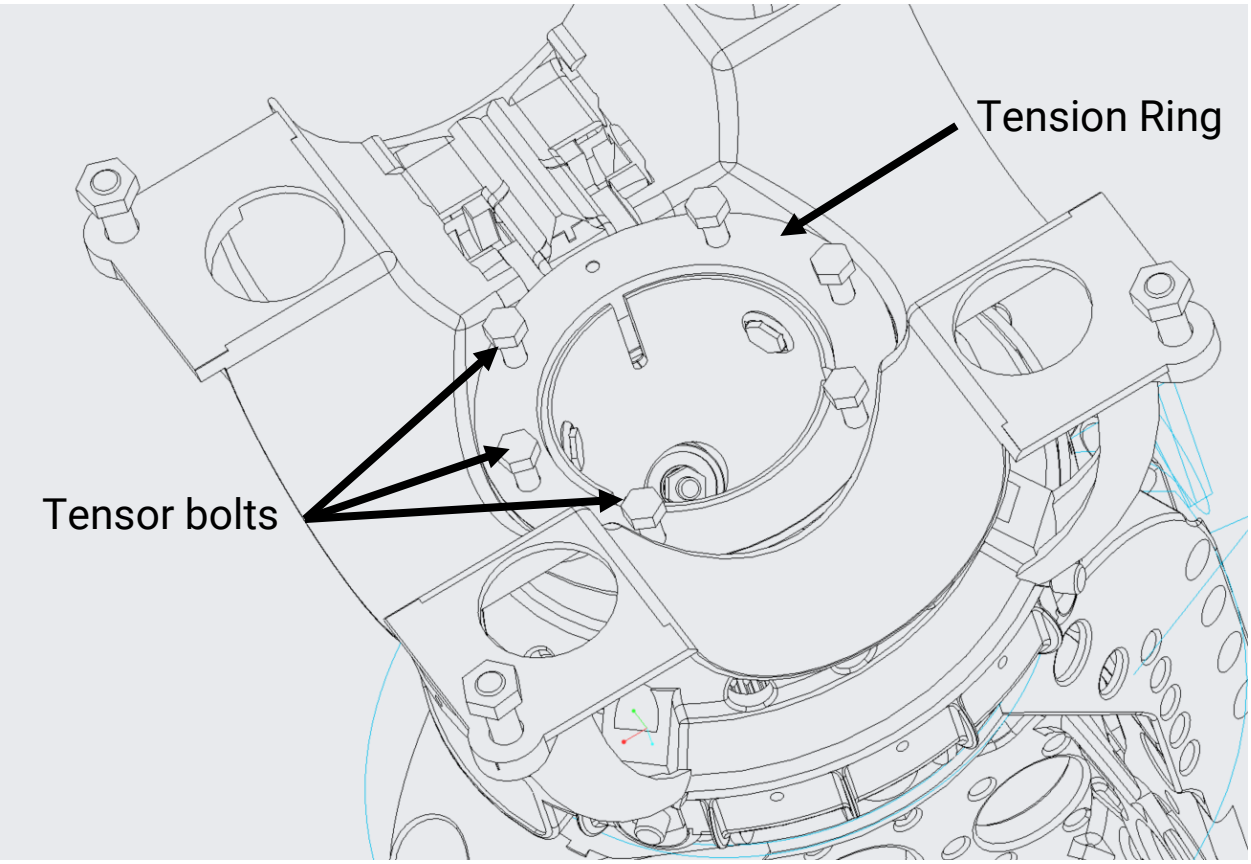
Base tension ring for GIM01, GIM1D and GIM03:

If you notice after extensive use that the 3D positioner base has a little bit of play on the horizontal plane gears, you can tighten the tension ring slightly to keep good pressure on the support bearing. A quarter turn is usually enough



The 6x Tensor bolts are never fully tightened, and they should not be.
Do not use mechanical wrench.
Do not overtighten the tensor bolt.

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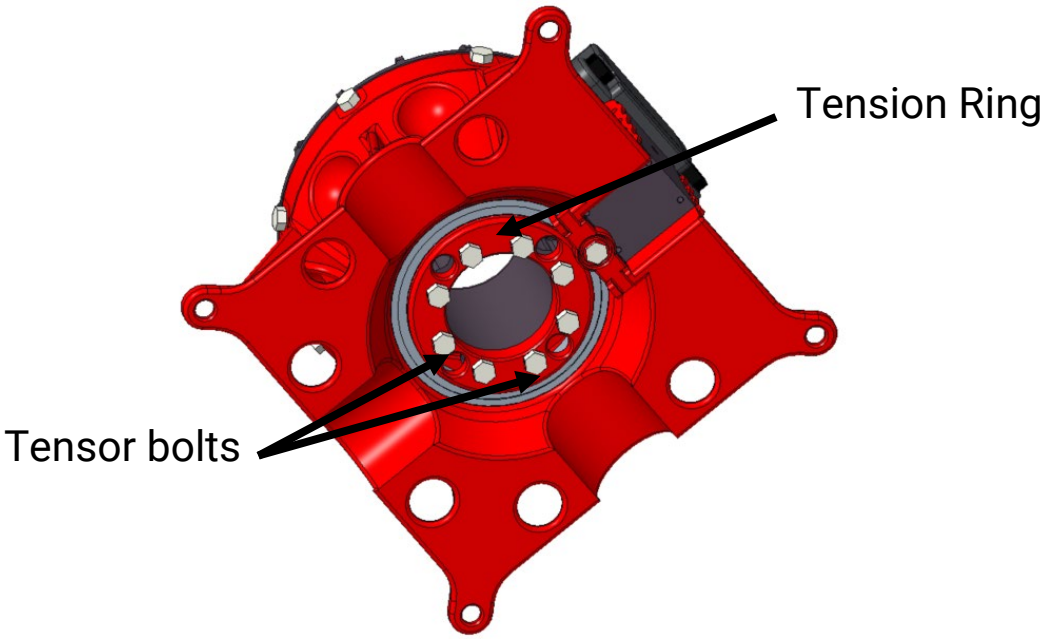
Tension adjusters for GIM04H Base type

GIM04H positioner base has a tension ring at its bottom to make sure the rotor stays flat on its bearing.
8 x M6 bolts are forcing the rotor against the bearings.



The 8x Tensor Bolts are never fully tightened, and they should not be.
Do not use mechanical wrenches. Do not overtighten the tensor bolt.

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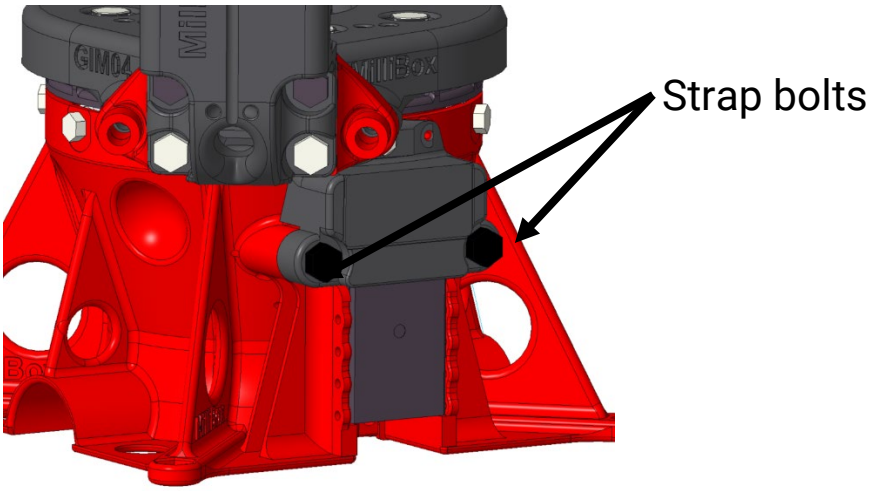
GIM04 positioner base has a motor strap forcing the base motor against the rotor gear. This is used to control the axis distance between the rotor and the motor to control gear backlash.
The strap should be adjusted to give a good pressure between the motor pinion and the rotor gear. But the strap should never be overtightened such that too much friction on the gears will create lockup, heavy wear, or failure.



The 2x Strap bolts are never fully tightened, and they should not be.
Do not use mechanical wrench or overtighten the tensor bolts.

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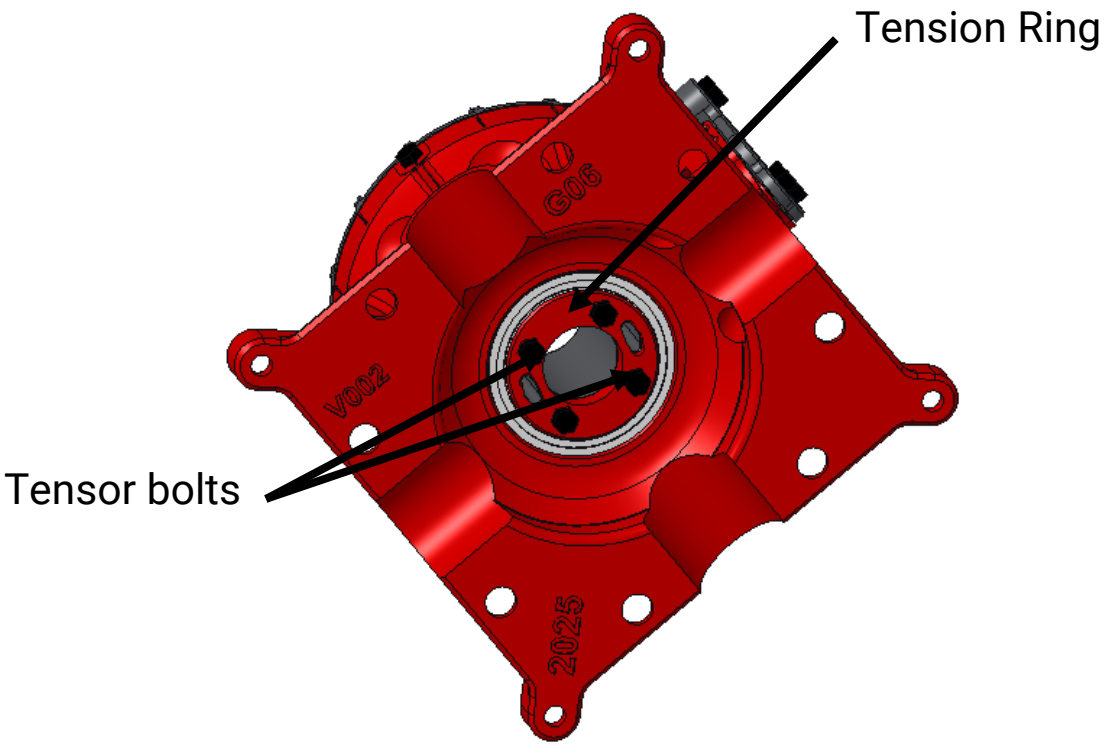
Tension adjusters for GIM06 type base

GIM06 positioner base has a tension ring at its bottom to make sure the rotor stays flat on its bearing.
4 x M6 bolts are forcing the rotor against the bearings.



The 4x Tensor Bolts are never fully tightened, and they should not be.
Do not use mechanical wrenches. Do not overtighten the tensor bolt.

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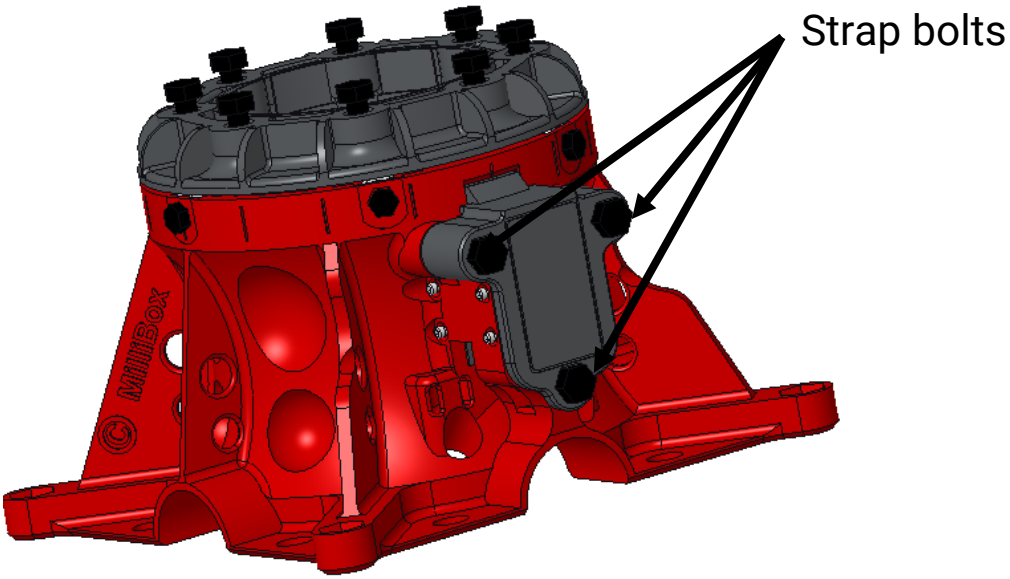
GIM06 positioner base has a motor strap forcing the base motor against the rotor gear. This is used to control the axis distance between the rotor and the motor to control gear backlash.
The strap should be adjusted to give a good pressure between the motor pinion and the rotor gear. But the strap should never be overtightened such that too much friction on the gears will create lockup, heavy wear, or failure.



The 3x Strap bolts are never fully tightened, and they should not be.
Do not use mechanical wrench or overtighten the tensor bolts.

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Regulations:

USA:

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at own expense.

Canada:

Class A ITE:
CAN ICES-3(A)/NMB-3(A)

EU:

Declaration of Conformity
Application of Council Directive(s): EU/EMC Directive 2014/30/EU
Standards to which Conformity is Declared: Milliwave Silicon Solutions, Inc.
Class A
Declarer's Name: Milliwave Silicon Solutions, Inc.
Declarer's Address:
429 Camille Cir, Unit 17,
San Jose, CA 95134
Type of Equipment: MilliBox

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Dynamixel is a Trademark of ROBOTIS CO., LTD
NiMax is a property of NI Corporation
VISA is maintained by IVI Foundation
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Versions:

Document	Version	Rel. date	Changes
HS-MBX02	001	3/28/2018	Initial version
HS-MBX02	002	9/10/2018	New release package includes R+ manager Support for Python 2.7 and 3.6 natively
HS-GIM0x	003	8/22/2019	Major overhaul For Release 14 and newer, Include GIM01 and GIM03 compatibility Added support for MacOS Horn description GIM03 mechanical description
HS-GIM0x	004	9/19/2019	Update Laser usage warning. Added test integration setup section
HS-GIM0x	005	11/04/2019	Update warnings. Added regulatory section
HS-GIM0x	006	02/02/2020	For release 15 and above Added Velocity control Added direct Move menu Integrated GPIB sample controller
HS-GIM0x	007	02/19/2020	For release 16 and above Complete overhaul of GPIB sample controller New menu function for printing GPIB resources
HS-GIM0x	017	04/19/2020	For release 17 and above Major overhaul and new features: • <y> to list and select GPIB resource • <x> to get current 3D positioner location and power measurement • <1> to start a 1D sweep

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			• <2> to start 2D sweep • <3> to start 1D sweep in V and H (E-plane and H-plane) • CSV files now include the header and do not have extra lines between data points • instrument.py • Added many new functions with basic visa communications • Added some common SCPI commands for spectrum analyzers and signal generators. • Added an optional name tag to captured data record files. • User Manual version and code release version are synchronized.
HS-GIM0x	019	01/26/2021	For release 19 and above Major overall and new features: • Support for GIM1D positioner • Improve mbx_accuracy • Add non-integer step size for positioner movement • Add elapsed time report for measurement sweeps • New accuracy setting ("e") and accuracy modes for STANDARD, HIGH, and VERY HIGH • ABORT plot using esc key • Support Anritsu MS464x (VectorStar) object in instrument.py • Plots of 2D sweeps can handle VNA data (freq sweep) and generates 3 plots (low, mid, high) • add option to configure SG/SA or VNA • mbx.py: select between SA or VNA at startup and initialize equipment. • menu option "f" to force re-initialization, • offset during initialization SW bugfix • Selection of VNA vs. Spectrum Analyzer is persistent across power cycles. • Move R+ manager, Manual USB driver settings and Tension Ring to new troubleshoot section.

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HS-GIM0x	019-1	04/09/2021	Minor document fix • Added pyVISA-py install, to be able to run when no instruments are installed.
HS-GIM0x	020	07/29/2021	For release 20 and above: New major features and additions: • GIM04 base support • GIM04 X-Pol support • add polarization control and report • compatibility with Python 3.x • VISA shell for SCPI command test and debug • standalone program to test instrument drivers • auto detection of Instruments by IDN • instrument whitelist to register new drivers • auto reconnect to last instruments and config • new instrument supported: • Keysight/Agilent VNA • R&S VNA • Agilent PNA • add combo instrument SG+SA Other improvements: • acceleration limiter for GIM04 H and V and GIM03 V • turn off torque option when leaving program. • straightened program flow structure • add default frequency setting. • simultaneous motor motion • new class name for instruments. • stop continuous trigger between step in VNA mode • document py-VISApy module required when no VISA drivers installed.

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			• time out on SCPI commands failure • add current position to main menu • improved isMoving functions • remove unused Dynamixel files
HS-GIM0x	021	01/09/2022	New major features and additions: • New cleaner directory structure • Velocity setting is not retained across power cycle • Change Desktop Icon Path to reflect new directory structure • Use HIGH accuracy setting as default when none specified. • Log commands and responses from mbx_visa_shell.py to file visa_log.txt • Print software version in shell • Fixes related to initial velocity settings
HS-GIM0x	021.1	02/05/2022	New features and additions: • SOCKET support for integration with software instruments. • Description of Python 3.x installation. • Description of new file `mbx_scpi_connection.py` function.
HS-GIM0x	021.2	04/20/2022	New features and additions: • Improved MacOS support in the code and in the documentation
HS-GIM0x	022	08/12/2022	New features and additions: • Added support for GIM05. • Zig-zag plot pattern • Elapse time presentation during sweeps • Electronic auto-align function for all positioners. • Abort before starting plots using ESC.

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			• Removed “standard” position accuracy. • Single trigger support for some instruments • New 2D heatmap plot.
HS-GIM0x	022.1	09/28/2022	Bug fix: • matplotlib bugfix due to new module release breaking mbx plot functions. New features and additions: • Vertical Adjustment for latest GIM05
HS-GIM0x	023	10/13/2023	New features and additions: • Complete Main Menu redesign, key remapping to streamline control, organized in sections for usability. • Set HOME position is now key 0 and prompt confirmation to prevent accidental press of ENTER key. • Added new calibration and correction menu, for gain and absolute power measurement. • Added direct measurement to file capture. • New VNA supports Mag + Phase mode • Complete redesign of motor configuration and control. • New motor profile configuration user menu: velocity target, acceleration limiter, and position limiter. • Post-processing feature allows power summation of 2 orthogonal captures. • Menu for 3D print converts radiation pattern to .stl . • Redesigned top layer of mbx_functions.py for external API control.

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			• Display/hide test and demo mode menu. Improvement and Bug fix: • Improved robustness for maintaining HOME position through power cycle and software crash. • Fixed GIM05/04 HOME position restoration bug. • Remove test/diagnostic function from menu since it is done at bootup. • Document installation on Windows 11.
HS-GIM0x	023.1	09/01/2024	New features and additions: • New Support for GIM05_FIXED which is GIM05 without HOR05 motorized probe • Post-processing to calculate difference between data sets • Add functionality for repeated measurements to file Improvement and Bug fix: • GIM05A now identified with GIM1D in console log at startup • Add "quiet" option to suppress error messages during motor identification • Display estimated total time and elapsed time progress for all sweeps • on abort, VNA does now returns to continuous trigger • Equipment whitelist additions: - Agilent N524x - Agilent E8361A - HP 8722D • Post-processing to compute total power now starts at first point

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HS-GIM0x	024	01/31/2025	New features and additions: • Upgrade to latest Dynamixel SDK which eliminates all OS driver dependencies but adds pyserial Python module dependency. • Revoke Apache license and use GPL 3 license instead going forward. • Software now detects GIMs automatically, without needing to know the COM port or the baudrate. • Get current power measurement command now plots the data if it is VNA data. • Save current power measurement to file command now has an option to make multiple measurements. Improvement and Bug Fix: • More positioner connection debug messages added to facilitate troubleshooting. • Fixed bug for HV sweep with GIM04X, polarization is now correctly set to user input value. • mbx.cfg is now readable by Python 2, even if it was created by Python 3. • Equipment whitelist additions: - Keysight FieldFox VNA - Ceyear 3762 VNA - Anritsu 37269D Lightning VNA
HS-GIM0x	024_1	08/31/2025	New features and additions: • 24-1 is the first release to support GIM06 • Document support for GIM06 throughout

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Acknowledgments:

At MilliBox, we want to make our customers successful and are dedicated to communicating as much information as we can in the most accurate way possible. If you notice something missing or not well explained please let us know, this will help us get better.

THANK YOU!

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