



User Manual
version – 2025.11.12 | Target HEDscan Version: v0.11

Copyright

Copyright © 2025 FieldLine Medical. All rights reserved.

The content of this user manual, including but not limited to: text, images, diagrams, and other materials, is protected by copyright law. FieldLine Medical is the sole owner of the intellectual property rights as outlined in the following user manual.

No part of this user manual may be reproduced, distributed, or transmitted in any form or by any means, including photocopying, recording, or other electronic or mechanical methods, without the prior written permission of FieldLine Medical, except in the case of brief quotations embodied in critical reviews and certain other noncommercial uses permitted by copyright law.

HEDscan, FieldLine Medical and the FieldLine Medical logo are trademarks of FieldLine Medical.

Proprietary and Confidential.

Contact Information

For questions, technical support, or additional information, contact FieldLine Medical Support:

E-mail: support@fieldlineinc.com

Telephone: +1 (720) 643-5813

Disclaimer

This user manual provides essential information for the safe and effective use of HEDscan. Users are strongly advised to read and understand the contents of this manual before operating the device.

Intended Use

HEDscan is intended for investigational use only. Any use outside the specified intended purpose may result in unintended consequences, and the manufacturer disclaims any responsibility for such usage.

User Responsibility

Users are responsible for using HEDscan in accordance with the provided instructions. Failure to follow the guidelines outlined in this manual may result in improper device operation and potential risks to the user.

Warning and Precautions

Users must adhere to all warnings and precautions outlined in this manual to ensure the safe and effective use of HEDscan. FieldLine Medical is not liable for any injury, damage, or adverse events resulting from failure to follow the warnings and precautions provided.

Maintenance and Servicing

Only authorized personnel should perform maintenance and servicing of HEDscan. Unauthorized modifications may compromise device safety and functionality. Follow the update protocol outlined in this manual to ensure optimal device performance.

Regulatory Compliance

This device is for investigational use only and does not currently have any certification from a regulatory authority.

Limited Warranty

FieldLine Medical provides a limited warranty as outlined in the warranty document received with HEDscan. Any unauthorized modifications or use outside the specified conditions may void the warranty.

FieldLine Medical has taken care to include accurate and up to date information in the following manual. However, it does not make any warranties, conditions, or representations as to its accuracy or completeness.

FieldLine Medical assumes no liability for use of this document if any unauthorized changes to the content or format have been made.

FieldLine Medical reserves the right to update and change HEDscan without further notice to improve reliability, function, or design.

Table of Contents

Contents

Copyright	2
Contact Information	2
Disclaimer	3
Intended Use.....	3
User Responsibility	3
Warning and Precautions.....	3
Maintenance and Servicing	3
Regulatory Compliance	3
Limited Warranty	3
Table of Contents.....	4
Table of Figures	7
Table of Tables.....	10
Device Set-Up.....	11
HEDscan Components	11
Installation Requirements	15
Hardware Overview.....	16
OPM-V3	16
Adult Helmet (Beta 2).....	18
Common Helmet Terms	19
Beta 2 OPM Sleeve Installation	21
Installing OPMs into Beta 2 Helmet	23
Beta 2 Sensor Position Names	25
Chassis Overview	27
Chassis Front.....	27
Chassis Rear	28
Multiple Chassis Configuration	39
Panel Coils	41
Chair	42
System Administration.....	43

HEDscan Admin User	43
HEDscan User	43
Using HEDscan	44
HEDscan System Startup	44
Launching the GUI via icon	44
Selecting System	45
HEDscan GUI Layout	46
Banner	49
Header	72
Views	73
Chassis View	78
Footer	82
Console Commands	82
HEDscan Quick Start Guide	88
Initial Connection	88
Restart Sensors	89
Failed OPM	90
Initialize System	91
Head Localization	93
Accessory I/O Configuration	95
HEDscan Updates	96
HEDscan API	99
Safety Notices	100
Troubleshooting	101
Appendices	102
Appendix A – Revision History	102
Appendix B – Update FIF Script	104
Helmetscan Analysis	105
HPI Location Incorporation	106
Appendix C – Example Console Command Script	107
Appendix D – HPI	108
Create HPI Operation Scripts	108
Perform HPI Scan	111

HPI Scan Analysis Script	112
Appendix E – Network Configuration.....	117

Table of Figures

Figure 1 – Helmet	12
Figure 2 - Chassis.....	12
Figure 3 – Panel Coils and Chair	13
Figure 4 – Computer.....	13
Figure 5 - Graphical User Interface (GUI).....	14
Figure 6 - ESD Wrist Strap.....	14
Figure 7 – OPM-V3 [Flat Cable]	16
Figure 8 – OPM-V3 [Round Cable].....	16
Figure 9 - OPM-V3 Specifications	17
Figure 10 – BETA 2 Adult Helmet (front view)	18
Figure 11 - Beta 2 Sleeve	19
Figure 12 - Beta 2 Sleeve and Trigger Assembly	20
Figure 13 - Beta 2 Hammock	20
Figure 14 - OPM Installation into Sleeve	21
Figure 15 - Installation Verification.....	21
Figure 16 - Set Screw.....	22
Figure 17 - Seat Cable	22
Figure 18 - Sleeve Installation into Helmet.....	23
Figure 19 - Inserted OPM	23
Figure 20 - OPM Removal from Beta 2.....	24
Figure 21 – Beta 2 Layout	25
Figure 22 - 3D Helmet View	26
Figure 23 - Chassis (Front View)	27
Figure 24 - Chassis Touch Screen.....	27
Figure 25 - Chassis Rear Example 2.....	28
Figure 26 - Sensor Card	29
Figure 27 - Helmet Driver.....	30

Figure 28 - HPI Card.....	32
Figure 29 - FieldLine Medical HPI V1.....	33
Figure 30 - Analog Input Card	34
Figure 31 - Analog Output Card	35
Figure 32 - Digital Input Card	36
Figure 33 - Compute Module	38
Figure 34 - PTC.....	39
Figure 35 - Multi Chassis Rack.....	40
Figure 36 – Panel Coils.....	41
Figure 37 – Chair.....	42
Figure 38 – HEDscan Icon	44
Figure 39 – HEDscan Select	45
Figure 40 - Chassis View Labeled.....	47
Figure 41 - 2D View Labeled	48
Figure 42 – Data Visualizer	50
Figure 43 – Channel Select Dialog	53
Figure 44 - Filter Select Dialog	54
Figure 45 - Configured Filter Dialog	55
Figure 46 – Data Visualizer – FFT	56
Figure 47 - Axis Settings Dialog	58
Figure 48 - Default Recorder	60
Figure 49 - Recording Types	61
Figure 50 - Recording Paths.....	61
Figure 51 - Recording Warnings.....	62
Figure 52 - No Sensor Localization.....	62
Figure 53 - Active Recording	63
Figure 54 - Disk Utilization	64
Figure 55 - Settings (Systems Tab).....	65
Figure 56 - Settings (Update Tab).....	66

Figure 57 - Settings (LSL Tab)	67
Figure 58 - Settings (HPI Config Tab)	68
Figure 59 - Settings (Trigger Config).....	69
Figure 60 - Trigger Test Box	70
Figure 61 - Settings (About Tab)	71
Figure 62 - OPM Control Buttons	72
Figure 63 – Chassis Color Codes	74
Figure 64 - Right Click Menu	75
Figure 65 - Sensor Properties.....	75
Figure 66 - Sensor Select Menu.....	76
Figure 67 – Sensitive Axis Menu	77
Figure 68 - Chassis View	78
Figure 69 - 2D View	79
Figure 70 - 2D View Sensors Off	80
Figure 71 - 2D View Initialized	81
Figure 72 – Console.....	82
Figure 73 - View Toggle.....	87
Figure 74 - Power Options	87
Figure 75 – Initial Connection	88
Figure 76 – Ready to Initialize.....	89
Figure 77 – Failed Start.....	90
Figure 78 – Initialized Sensors with Localization.....	91
Figure 79 - Fully Localized	92
Figure 80 - Localized Head.....	94
Figure 81 - Accessory View	95
Figure 82 – Ubuntu Software Updater.....	96
Figure 83 – Update Dialog	97
Figure 84 – Out of Date Firmware.....	98
Figure 85 – HPI Localization Plot	116

Table of Tables

Table 1 - Digital Input Connection Table.....37

Table 2 – HEDscan Icons 49

Table 3 – Data Visualizer Icons51

Table 4 - Color Chart 73

Device Set-Up

The following section details HEDscan set up procedures. HEDscan will be installed by representatives from FieldLine Medical, either remotely or in person.

NOTE: User systems vary. Some items shown below may not be included in all systems.



CAUTION: Do not use any tools that may have magnetic tips, magnetic attachments, or the use of magnets in any way.

HEDscan Components

HEDscan systems can consist of the following components:

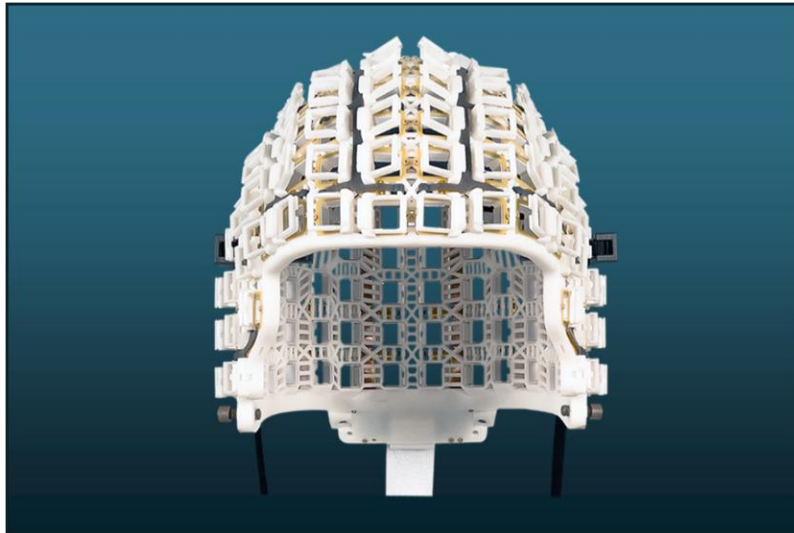


FIGURE 1 – HELMET

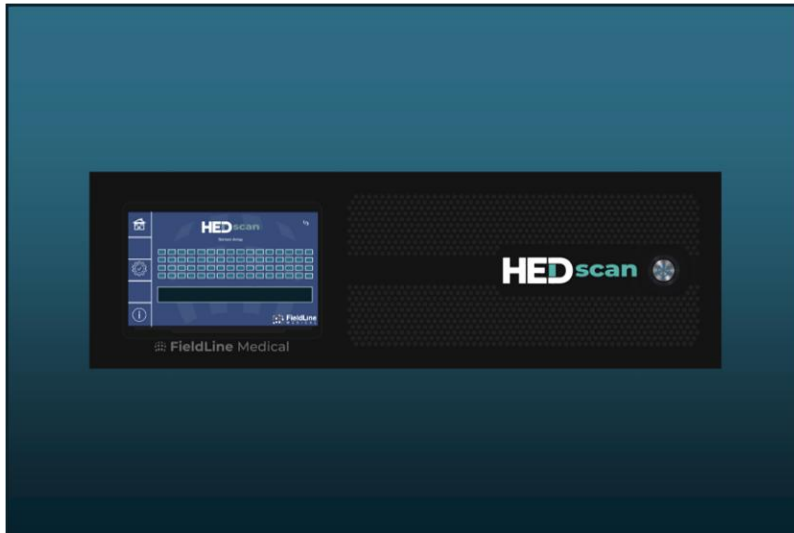


FIGURE 2 - CHASSIS



FIGURE 3 – PANEL COILS AND CHAIR



FIGURE 4 – COMPUTER



FIGURE 5 - GRAPHICAL USER INTERFACE (GUI)

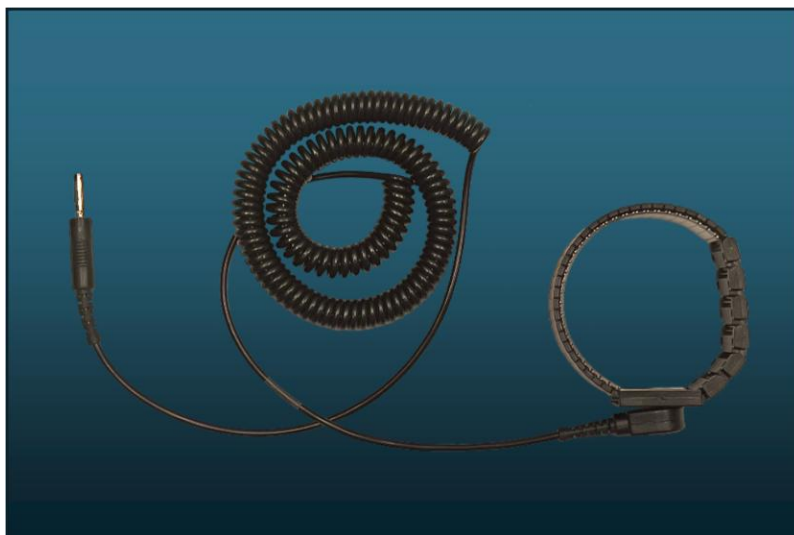


Figure 6 - ESD Wrist Strap

Installation Requirements

- HEDscan Chassis Power Supply requires 100-240 VAC (50-60Hz), 2.0 A
- HEDscan requires occasional network activity. Coordinate with IT or System administrator to assign HEDscan and coordinate any necessary updates to maintain the overall integrity of the components.
- HEDscan does not need to be connected to an external network to operate. However, updates are received via the internet and will need to be loaded onto the system locally when they are published. If the system is connected to the internet, it will be able to grab the updates seamlessly (when prompted by the user). FieldLine Medical strongly recommends maintaining the latest system firmware and software for the most optimal user experience.
- The control software for HEDscan has been designed and optimized for the computer delivered with the system. As such it is required for the use of the system.
- Third party hardware and software can be used and installed on the computer provided for HEDscan. However, FieldLine Medical cannot guarantee compatibility, nor support third-party software and hardware. Contact FieldLine Medical before interfacing the system with a third-party accessory.

Hardware Overview

The section below details the hardware that can be included with HEDscan.

OPM-V3

Below is a rendering of the FieldLine Medical Optically Pumped Magnetometer-V3 [OPM-V3] with the optional Flat cable (Figure 7) or Round cable (Figure 8). The connector to the Sensor Card is a mini-HDMI.



FIGURE 7 – OPM-V3 [FLAT CABLE]



FIGURE 8 – OPM-V3 [ROUND CABLE]

Figure 9 shows the dimensions and orientation of the OPM-V3.

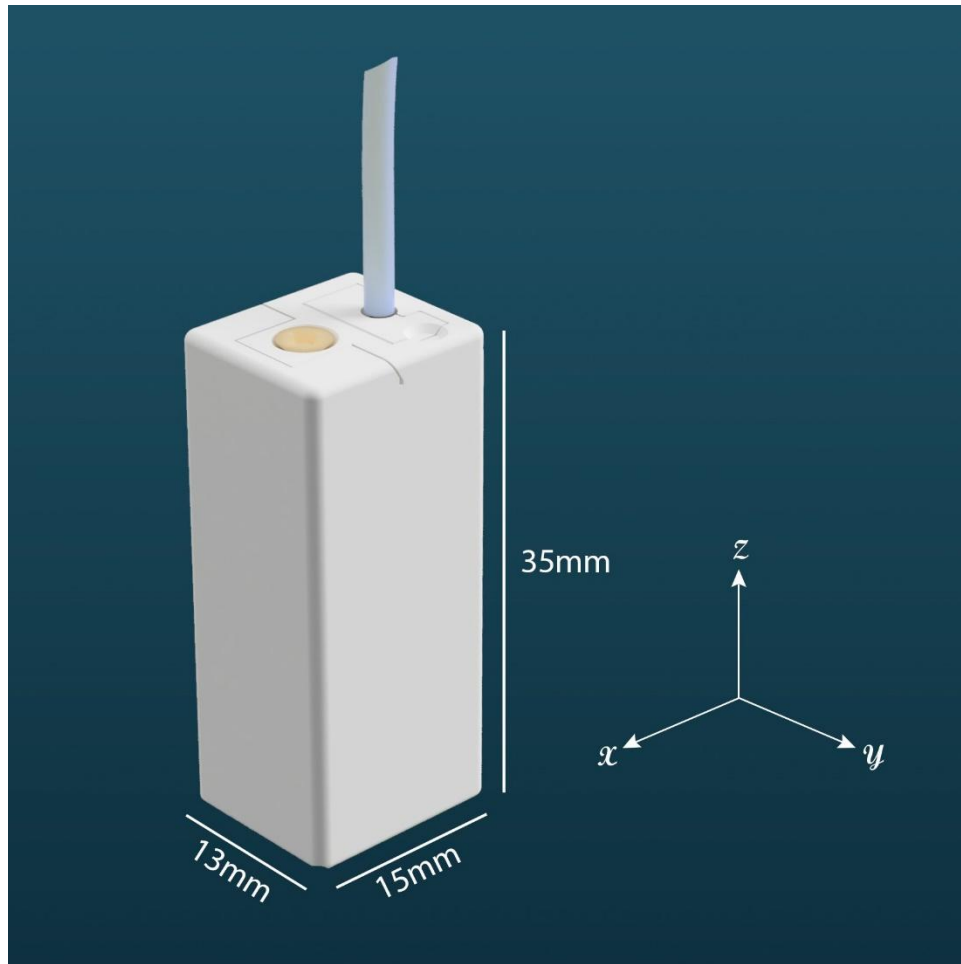


FIGURE 9 - OPM-V3 SPECIFICATIONS

⚠ CAUTION: OPMs are extremely sensitive to static electricity. Whenever inserting sensors into the Sensor Card wear a wrist strap that is properly grounded.

⚠ CAUTION: OPM cables should not be bent. The maximum bend radius for either cable is 1 inch.

⚠ CAUTION: OPMs can be damaged from exposure to highly ferrous materials. Avoid exposing sensor head to magnetically charged or conductive materials.

The neoprene tip must be removed before taking the sensors out of the sleeve. To remove the sensors from the sleeves, use the Alan key provided to loosen the set screw on the top. Then slide the sensor out sideways.

⚠ CAUTION: Do not operate the OPM in contact with skin without the neoprene tip between sensors and skin.

Adult Helmet (Beta 2)

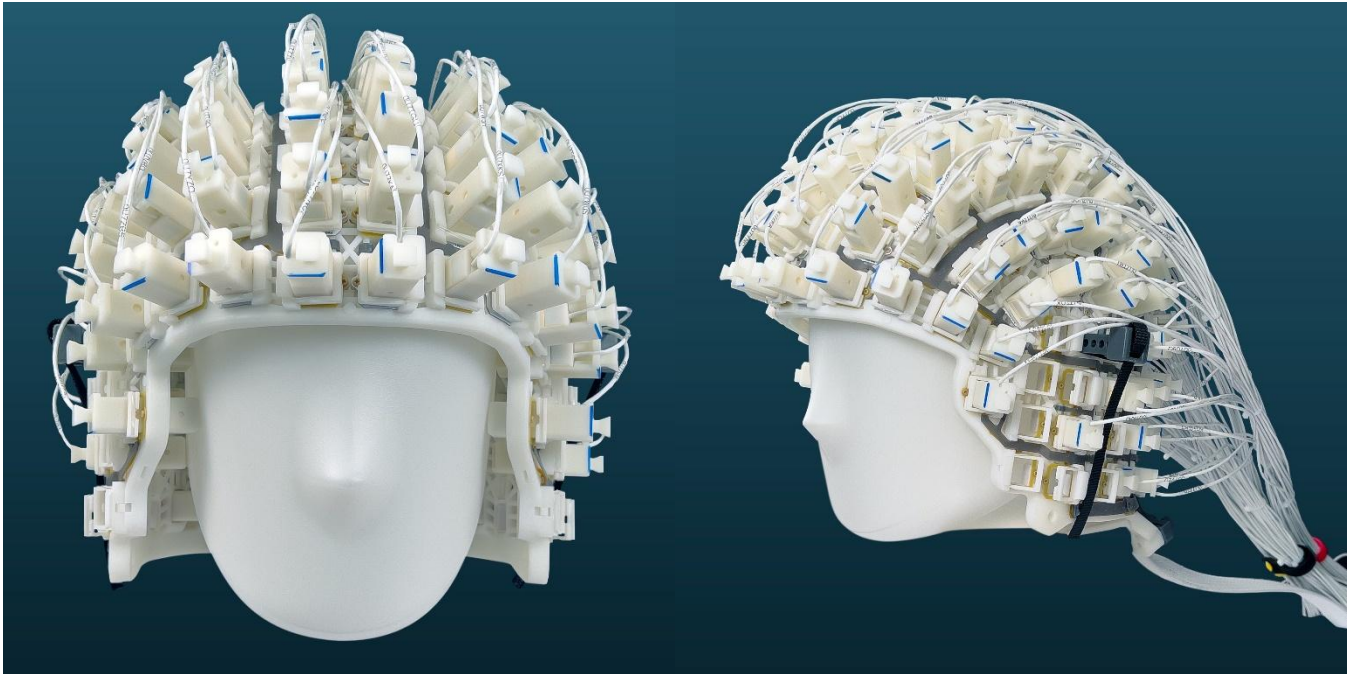


FIGURE 10 – BETA 2 ADULT HELMET (FRONT VIEW)

Featuring slots for up to 144 OPMs, the helmet can also optionally include a hammock to support the head in a supine position. The following section will detail proper operating procedure when handling the helmet.

Common Helmet Terms

Sleeve – To operate a V3 Sensor in the Beta 2 Helmet it must be installed in a sleeve (see Figure 11 and callout 1 on Figure 12)



FIGURE 11 - BETA 2 SLEEVE

Trigger – OPMs installed in sleeves are then inserted into the helmet into the “trigger” assembly (see callout 2 on Figure 12). This assembly has a ratcheting mechanism to hold the sensor in place as it is gently pressed down onto the patient’s head.

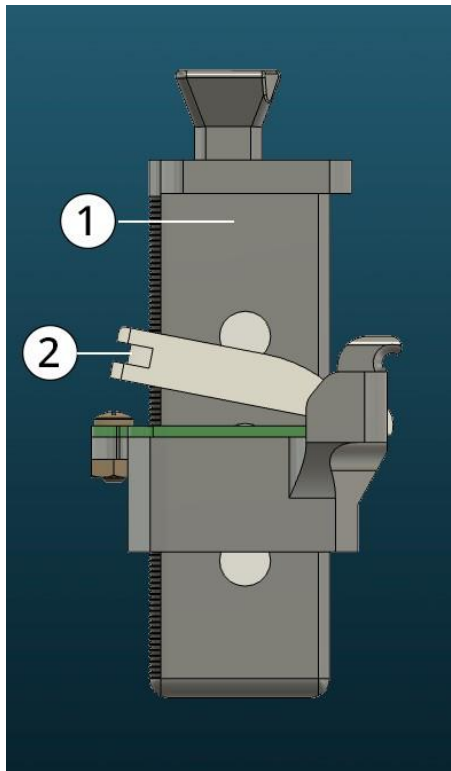


FIGURE 12 - BETA 2 SLEEVE AND TRIGGER ASSEMBLY

Hammock – The hammock (Figure 13) is necessary to support the head when a patient is lying on a bed. The hammock is adjustable and removable. When sitting upright the hammock can be unnecessary.

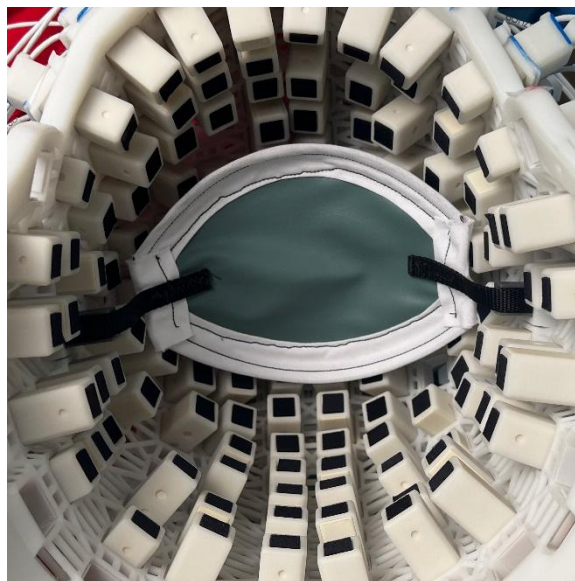



FIGURE 13 - BETA 2 HAMMOCK

Beta 2 OPM Sleeve Installation

To operate in the Beta 2 helmet an OPM must be installed into a sleeve. In the event an OPM needs to be swapped with another, it will be necessary to remove the OPM from the sleeve. The following instructions discuss how to install an OPM into a sleeve. To remove, simply reverse the instructions.

1. Insert OPM into sleeve (Figure 14). If uninstalling the OPM, FieldLine Medical has provided a tool to help pop the OPM out of the sleeve.

 **CAUTION:** Do NOT pull the OPM out of the sleeve via the cable connection. This can irreparably damage the OPM.

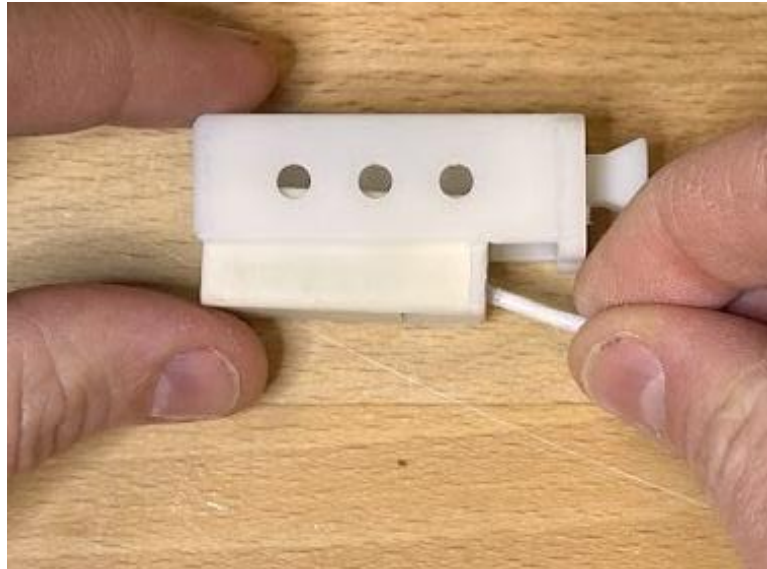


FIGURE 14 - OPM INSTALLATION INTO SLEEVE

2. Gently press OPM into sleeve until it is seated fully flush with the side of the sleeve (Figure 15)

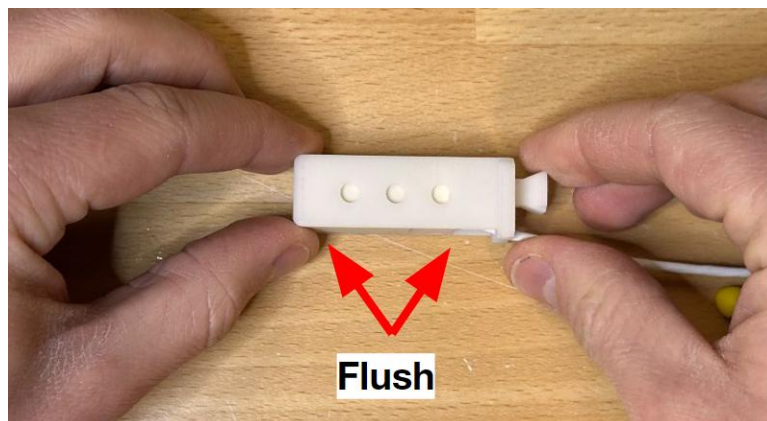


FIGURE 15 - INSTALLATION VERIFICATION

3. Once the OPM is installed tighten the set screw at the top of the sleeve with the provided 0.05" hex key (Figure 16)


 **CAUTION:** When using the hex key, be sure to not overtighten the screw. It is nylon and is easily stripped. Hand-tight is sufficient torque.



FIGURE 16 - SET SCREW

4. After torquing the set screw, seat the cable in the cable catch. (Figure 17) Proceed to install a new neoprene tip on the OPM. When preparing to remove an OPM from the housing it is necessary to peel off and discard the neoprene tip.

 **CAUTION:** FieldLine Medical cautions against operating an OPM without the provided neoprene tips.

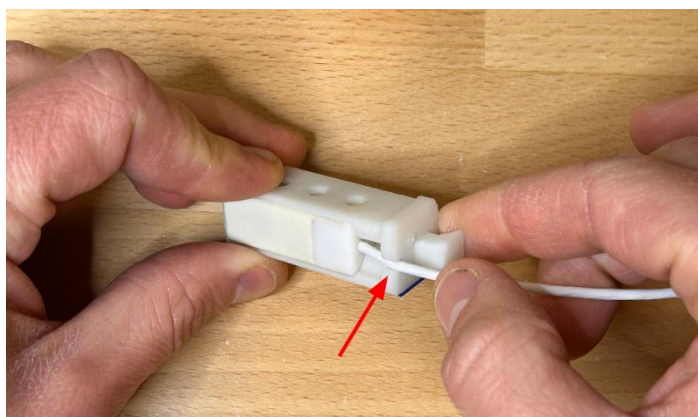


FIGURE 17 - SEAT CABLE

Installing OPMs into Beta 2 Helmet

To install an OPM into the Beta 2 helmet it is important to be aware that the sleeve is keyed to fit only one orientation on the helmet. The helmet and sleeves have been marked with a blue line to indicate the orientation. These lines must be matched to install the sensor. (Figure 18)

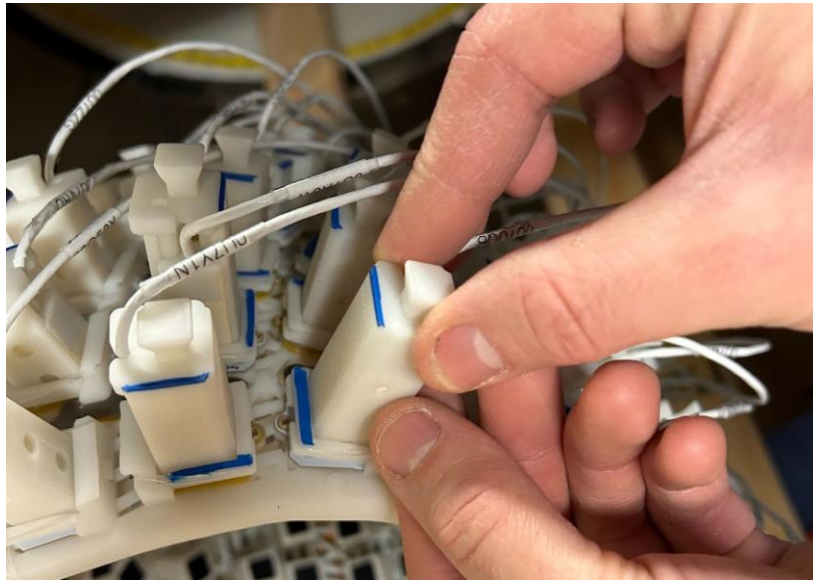


FIGURE 18 - SLEEVE INSTALLATION INTO HELMET

After installing the OPM into the helmet press it down to the desired position. FieldLine Medical recommends communicating with the patient during this process to limit discomfort as OPMs are being pressed in. (Figure 19).



FIGURE 19 - INSERTED OPM

To remove or release the OPM press down on the trigger release mechanism and then pull the OPM up. FieldLine Medical recommends using one hand to hold the release

down and another to pull the OPM out. To release the patient the OPM does not need to be completely removed, but rather pulled flush with the base of the helmet. See Figure 20.

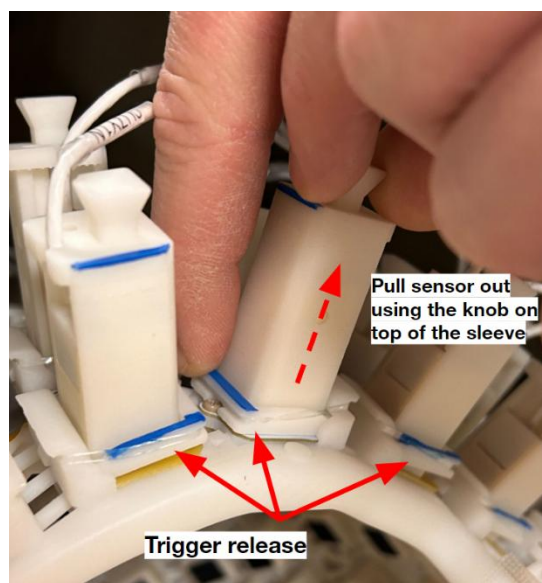


FIGURE 20 - OPM REMOVAL FROM BETA 2

Beta 2 Sensor Position Names

Figure 21 below demonstrates the naming convention for the Beta 2 Helmet. The slot convention is [Column] [Row], where Column is either [L]eft or [R]ight, and the Row is the number starting at 1, front to back. A printable, full resolution image (Beta2SensorLocations.png) is provided on the control computer at: </usr/share/hedscan/doc>. Figure 22 on the following page shows a 3D model of each helmet side as well.

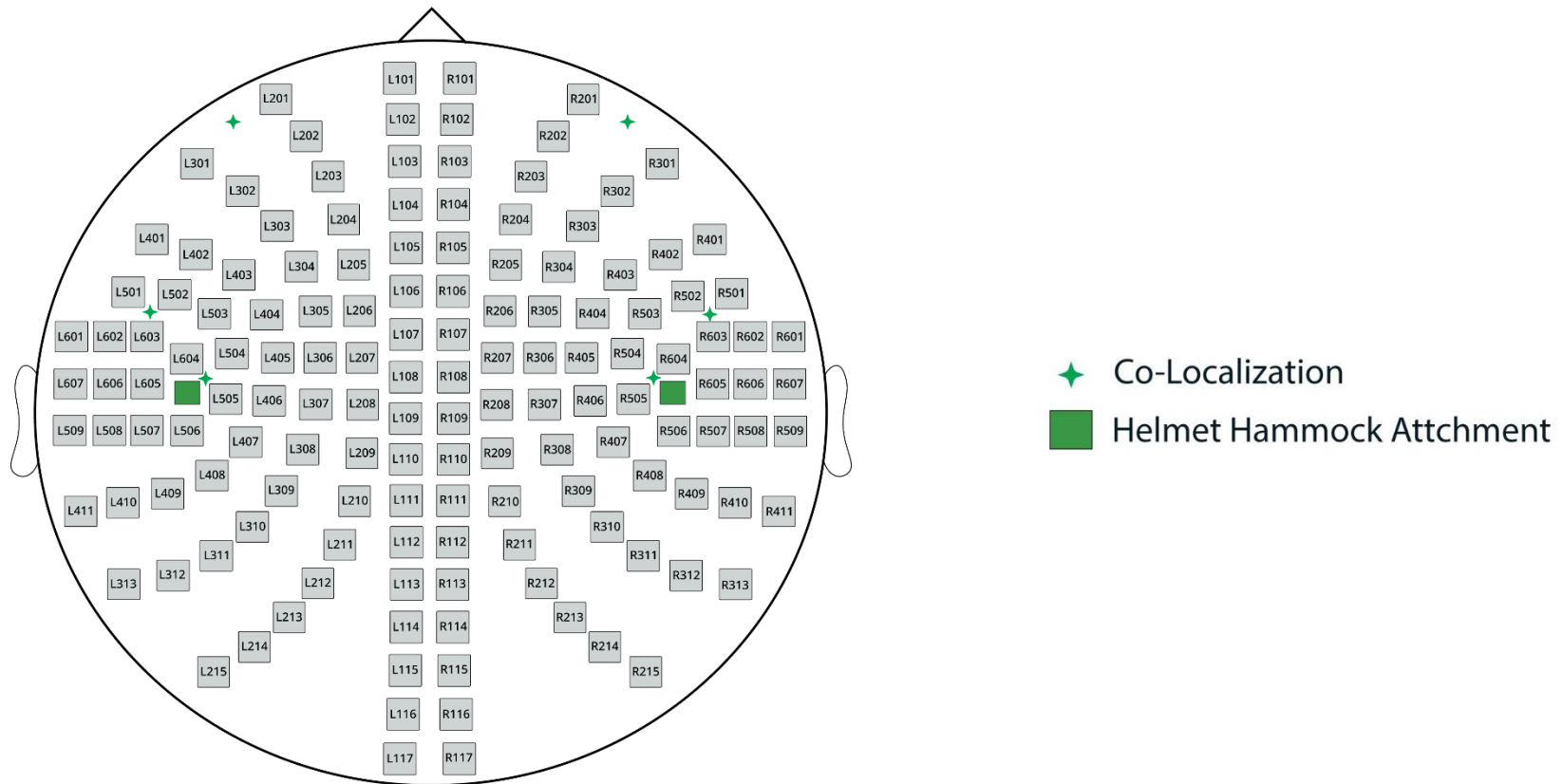


FIGURE 21 – BETA 2 LAYOUT

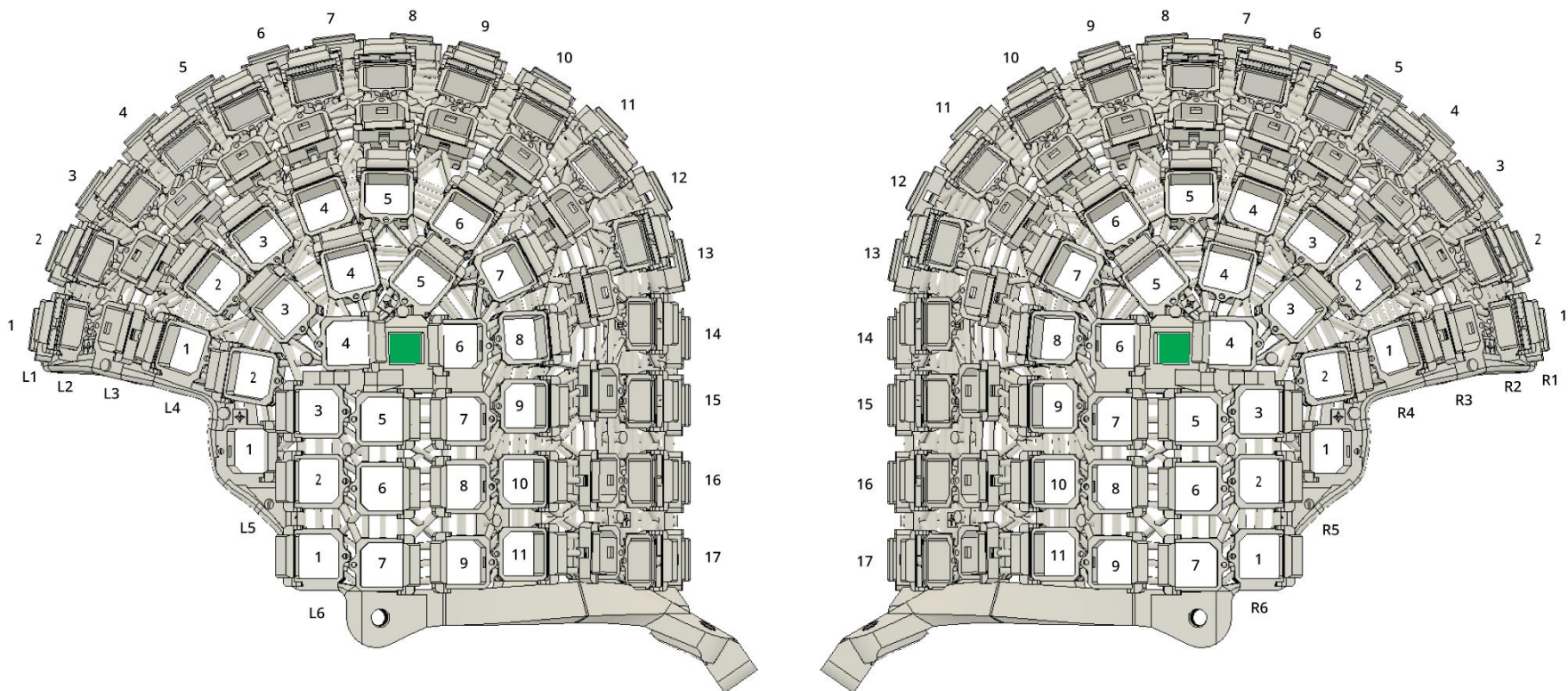


FIGURE 22 - 3D HELMET VIEW

Chassis Overview

The below section will detail the control electronics included with HEDscan.

Chassis Front

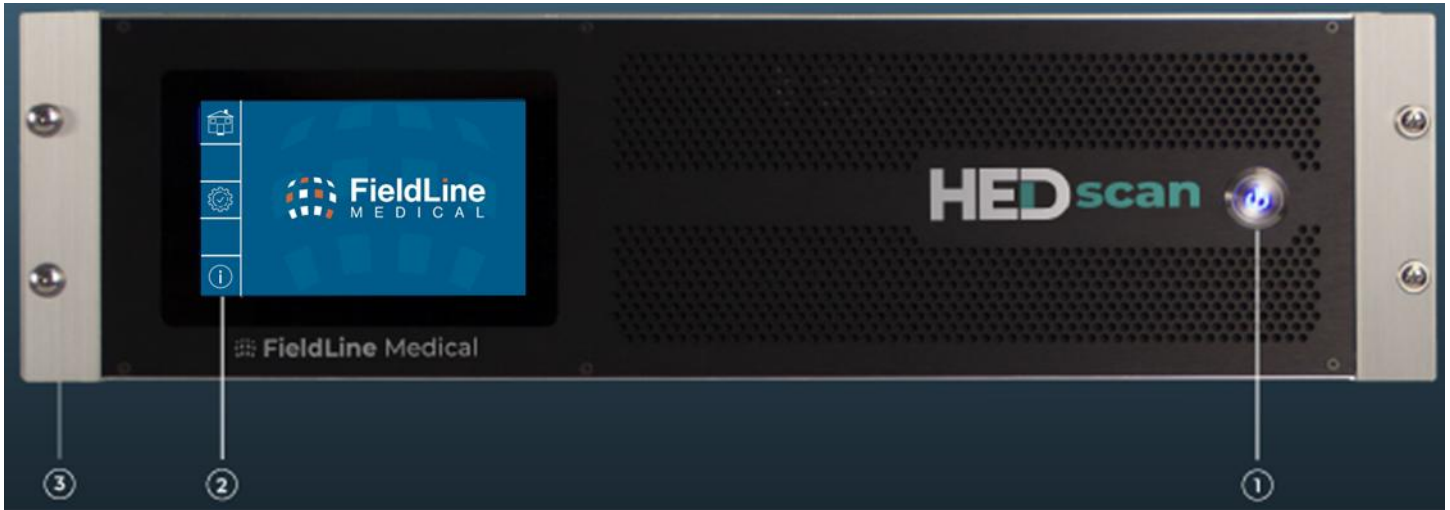


FIGURE 23 - CHASSIS (FRONT VIEW)

The front of the chassis is pictured in Figure 23.

1. Power Button – Illuminated solid blue when power is on (as pictured above). Will slowly blink while the system is starting up and remain solid when the system is operational. A short press of the button will initiate power down. A long press of the button will force power down.



Caution: Only force a power down if necessary, as file corruption can occur.

2. Touch Screen – The chassis user interface touch screen (Figure 24) has the following features:
 - a. Home – HEDscan Logo
 - b. Settings – Coming Soon
 - c. Info – Chassis Information including IP address and system name.



FIGURE 24 - CHASSIS TOUCH SCREEN

3. Mounting bracket for cabinet.

Chassis Rear



FIGURE 25 - CHASSIS REAR EXAMPLE 2

The accessory cards are located on the back of the chassis numbered 1-16 left to right. Figure 25 displays all the currently available HEDscan accessory cards. Each user system varies which purchased cards are present.

- 1) Analog Input
- 2) Analog Output
- 3) HPI
- 4) Helmet Card
- 5) Digital Input
- 6) Sensor Card
- 7) Blank Slot
- 8) Compute Module
 - a) MiniSAS connector for Chassis-to-Chassis connections
 - b) Ethernet Port
 - c) Development Port
- 10) Power Thermal Controller (PTC)



CAUTION: Make sure the front and rear of the chassis have adequate space (approximately 1 foot in front) to source air to maintain a safe operating environment for the system.

Sensor Card

Figure 26 below shows the HEDscan Sensor Card which drives up to four OPMs. Each port is a mini-HDMI connector which is keyed to prevent improper insertion.


 **CAUTION:** FieldLine Medical OPMs are static sensitive devices. It is essential to wear the provided ESD wrist strap when inserting and removing the OPMs. Additionally, OPMs should NOT be installed or uninstalled during system operation. Only exchange OPMs when all OPMs are powered off.



FIGURE 26 - SENSOR CARD

Helmet Driver Card

Figure 27 below pictures the Helmet Driver card. The four cables that connect to the HEDscan helmet will be connected to this card. FieldLine Medical representatives will demonstrate how to install the helmet card and cables.



FIGURE 27 - HELMET DRIVER

HELMET CABLE REMOVAL INSTRUCTIONS



CAUTION: Removing the helmet cables requires the removal of the helmet card. Use the provided ESD wrist strap to stay grounded.

1. Power down the system using either the GUI or a short press of the power button on the Front Panel. After the system has finished powering off (the front panel display and power button are no longer illuminated) flip the switch on the PTC to the off position.
2. Using the provided flat head screwdriver, unscrew the two retaining screws on the top and bottom of the helmet card holding it in position.
3. Using the handle on the bottom of the Helmet Driver gently disengage the card and remove it from the chassis.



CAUTION: The card should gently slide out. If there is resistance, stop work and call FieldLine Medical Support.

4. After removing the card take note of how the cables have been inserted. They should be identical.
5. Using the provided #1 Philips screwdriver take off the helmet cable retaining bracket pictured below.
6. Once the bracket is removed, one at a time and working from the right, gently open the retaining clip and remove each cable cables.
7. Proceed to slide cables out of the slot in the helmet driver. At this point it is possible to slide the helmet cables in and out of an MSR.
8. When ready to re-install the cables re-install them in the reverse order.
 - a. A minor bend in the FFC connector can be helpful when seating the cable fully into the connector.



CAUTION: Care must be taken when installing the cables as excess bending can result in damage.

9. After re-installing the helmet cables, re-insert the card into the chassis (the card should be flush with the chassis edge) and screw in the retaining screws until they are hand tight.
10. Power on the PTC power switch, and then re-power the chassis using the button on the front panel. Return to the GUI and make sure the helmet card is discovered. If the helmet is not discovered stop work and contact FieldLine Medical Support.

HPI Card

The HPI (Head Position Indicator) Card is pictured below in Figure 28. The inputs to the HPI card are standard 3.5 mm audio jacks. If extensions to the provided HPI coils are necessary, a standard audio cable will suffice. [Appendix D](#) provides an example to operate the HPI coils.



FIGURE 28 - HPI CARD

HPI coils provided by FieldLine Medical consist of 5 coils per layer in a 2-layer configuration. Figure 29 defines the coil geometry.

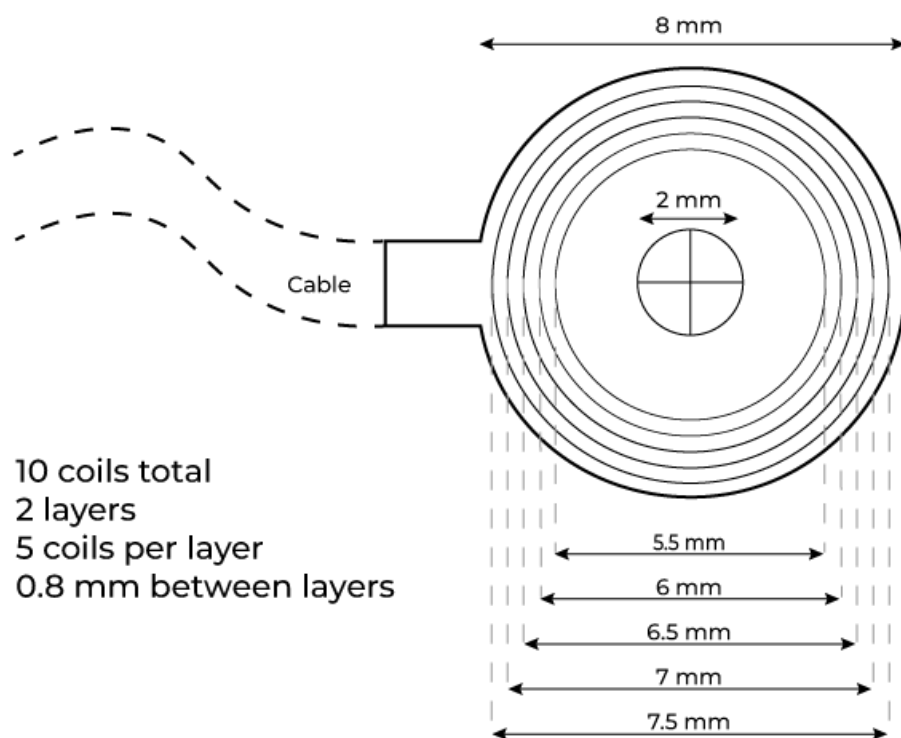


FIGURE 29 - FIELDLINE MEDICAL HPI VI

Analog Input Card

The Analog Input card has four black standard BNC connectors and is pictured in Figure 30. This card can accept $\pm 10\text{V}$ on each of its inputs, and samples using a 24bit ADC at a rate of 125kHz. The data received is synchronized with all other channels.



FIGURE 30 - ANALOG INPUT CARD

Analog Output Card

The Analog Output card has four white standard BNC connectors and is pictured in Figure 31. This card outputs up to $\pm 10V$ via a 16bit DAC on each of its channels at 125kHz. Users can configure the amplitude, frequency, phase, and offset of up to 28 unique waveforms that can be individually applied to each output. Additionally, users can add any combination of the 28 unique waveforms together on each channel to produce an even wider array of signals.



FIGURE 31 - ANALOG OUTPUT CARD

Digital Input Card

The digital input card, pictured in Figure 32, interfaces with a DB37 connector and has 32 inputs and 5 ground connections. The card accepts digital signals at varying voltages, up to 5V.



FIGURE 32 - DIGITAL INPUT CARD

Table 1 below is the pin mapping for the digital input card DB37 connector to each corresponding bit in the recorded data.

TABLE 1 - DIGITAL INPUT CONNECTION TABLE

DB37 Connector Pin	Corresponding Data Bit [31:0]
1	GND
2	0
3	1
4	2
5	3
6	4
7	5
8	6
9	7
10	GND
11	8
12	9
13	10
14	11
15	12
16	13
17	14
18	15
19	GND
20	16
21	17
22	18
23	19
24	20
25	21
26	22
27	23
28	GND
29	24
30	25
31	26
32	27
33	28
34	29
35	30
36	31
37	GND

Compute Module

The Compute Module controls communication across HEDscan and to the control computer. Communication to the computer is managed via gigabit ethernet through ethernet port (labeled B) in Figure 33. Label A is the mini-SAS connector. The SAS cables allow for back-channel communication when multiple chassis are daisy chained together. Data flows from the top port to the bottom port. Label C is a development port and should not be used by the user.

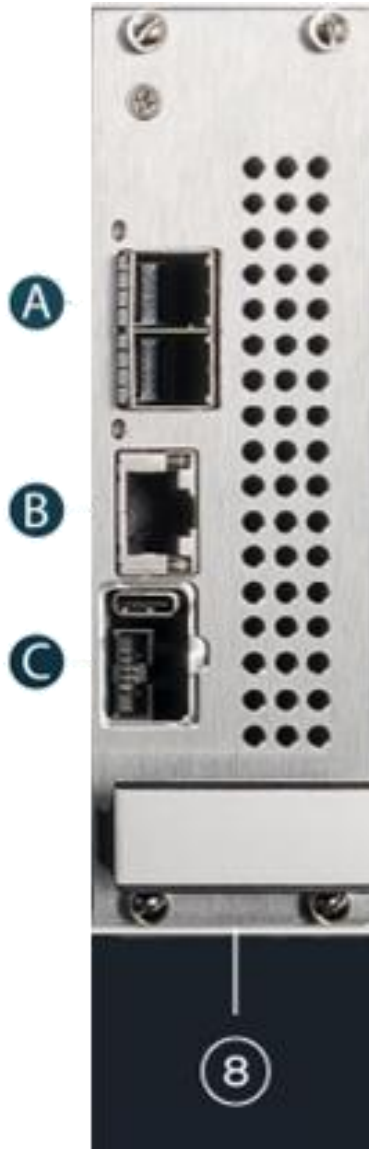


FIGURE 33 - COMPUTE MODULE

Power Thermal Controller (PTC)

The PTC provides the system power. The PTC provides $\pm 12\text{V}$ and 5V rails to the varying Accessory Cards and Compute Module. Additionally, the PTC monitors the temperature of varying points on all cards installed. It then adjusts the fan speed accordingly. If any of the cards are run more than 60°C the PTC will immediately power down all rails to allow the system to cool to safe levels.



FIGURE 34 - PTC

The connector on the rear of the power supply is a standard IEC 320-C14. There is also a power switch to control power to the PTC. This switch only controls power for the PTC, not for the other HEDscan modules. On newer PTC releases (image on the right) there is also a small power button that can power on the accessory modules like the front panel power switch.

Multiple Chassis Configuration

When using HEDscan in a multiple chassis configuration some considerations should be taken.

1. HEDscan should be powered on from TOP to BOTTOM. This will allow the system to come up in a known configuration and lead to faster boot times. If the power sequencing is done out of order the boot times may be increased. Additionally, if powering down via the power buttons the same order should be adhered.


2. Only one ethernet connection is necessary. It should be installed in the ethernet port on the bottom chassis.
3.  Caution: Never swap the chassis-to-chassis cables while the system is powered. These cables are not designed to be swapped while the system is in operation and can permanently damage the compute module.
4. If updating HEDscan from an update 0.3 or older please contact FieldLine Medical before proceeding.
5. Figure 35 shows a rack in a multi-chassis configuration.



FIGURE 35 - MULTI CHASSIS RACK

Panel Coils

The FieldLine panel coils (pictured in Figure 36) can produce up to $\pm 200\text{nT}$ of field in the B_z , B_y , and B_x directions. Currently they are only suitable for reducing the DC field offset in the shielded room.

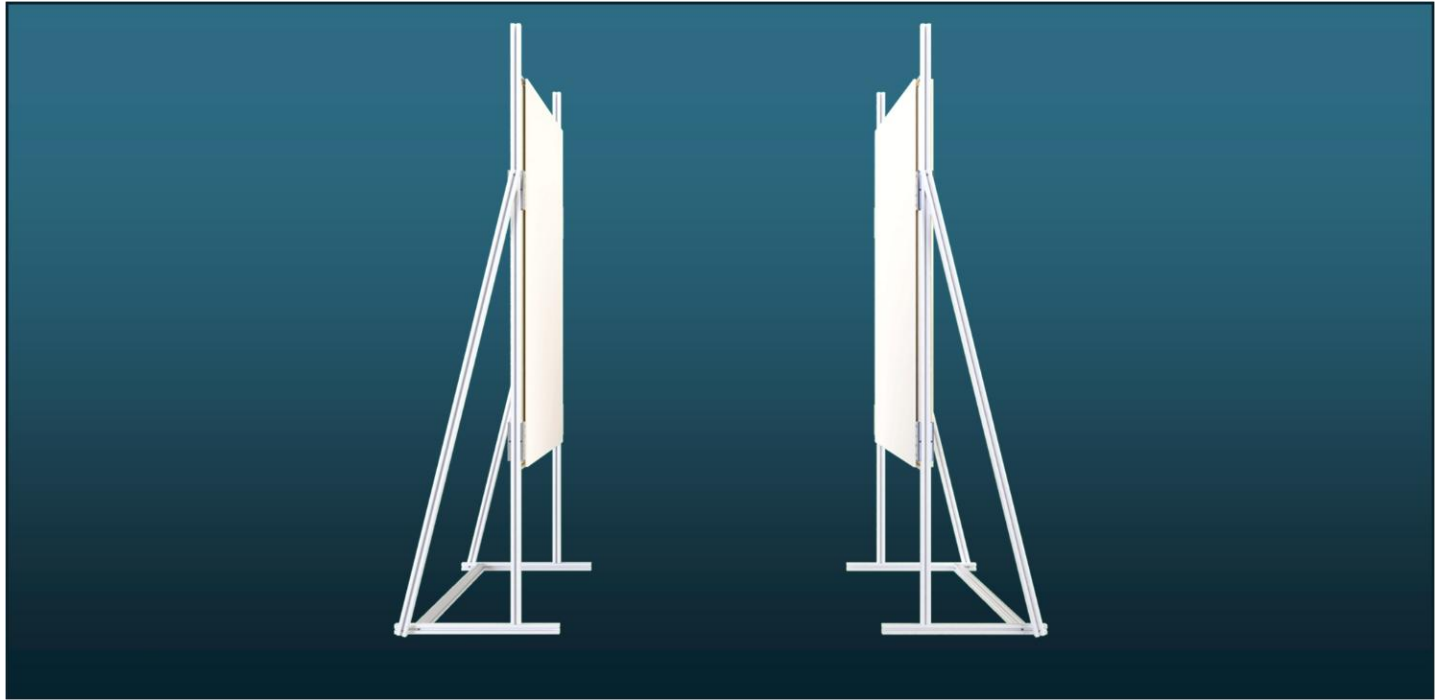



FIGURE 36 – PANEL COILS

The panel coils consist of the following:

- 2x standard ethernet cable to connect the two systems together inside the shielded area, and to connect to the external control module.
- 1x large power cable with branching outputs to power each panel that exits the shielded area and connects to the control module.
- 1x control module to power and provide communication to the panel coils.
- 1x USB Type A to USB Type B cable.

The panel coils are controlled via a specific panel coil driver software separate from the HEDscan GUI.

 **CAUTION:** Panel coils can fall over if knocked into, use the weighted bags provided to stabilize them once in position.

 **CAUTION:** Panel coils are heavy. Use two people to move them and avoid attempting to pivot them on their base legs.

Chair

Pictured below in Figure 37 is an optional chair that the HEDscan helmet can be mounted to using the provided helmet mount.



FIGURE 37 – CHAIR

The Chair is non-magnetic, reclinable, and has an optionally extendable footrest.

System Administration

HEDscan will be installed by representatives of FieldLine Medical. The software to operate HEDscan is pre-installed on the computer provided. The computer has Xubuntu 22.04 installed. Periodically FieldLine Medical will push updates for HEDscan. See the section for HEDscan Updates for information on installing the update. To receive these updates HEDscan will need network access. This can be provided via the standard ethernet port located on the Compute Module.

HEDscan Admin User

FieldLine Medical recommends there be at least one User Admin / IT Admin that will be responsible for the delegation of users, overall system performance, updates, modifications, and troubleshooting/system support.

This is necessary to keep track of users and system performance and should be set up prior to running the HEDscan system

HEDscan User

FieldLine Medical recommends that the HEDscan admin create unique user profiles for each operator of the system. Having each user log into and out of the HEDscan system ensures that user specific preferences, profiles, and testing setups are properly protected. FieldLine Medical is not responsible for user access or permissions.

Using HEDscan

The following section will detail how to navigate the HEDscan GUI and operate the system.

HEDscan System Startup

HEDscan is a networked device and must be connected to either the local network or the HEDscan workstation. If not connected the system will not fully boot. When installed in a standard rack HEDscan is powered via a power strip which is connected to the wall power. A green switch on the front indicates if power is applied. To turn HEDscan on follow the following three steps:

1. Toggle power strip switch to the on position.
2. Toggle the PTC power switch on each chassis to the on position.
3. Starting from the top mounted chassis short press each power button (either on the PTC (for newer models) or the button on the front of the chassis) from the top chassis down to the bottom chassis.

When the system boots the fan will start off at a higher level and then come down as communication is established. Boot-up takes approximately 2 minutes for a three chassis system.

Launching the GUI via icon

To launch the HEDscan GUI on the workstation the user can select the icon shown in Figure 38, or from a terminal run:

```
./hedscan-gui
```



FIGURE 38 – HEDSCAN ICON

Selecting System

All available HEDscan systems located on the available network are shown on an initial connection screen. Select the correct system and select “Connect”. See Figure 39.

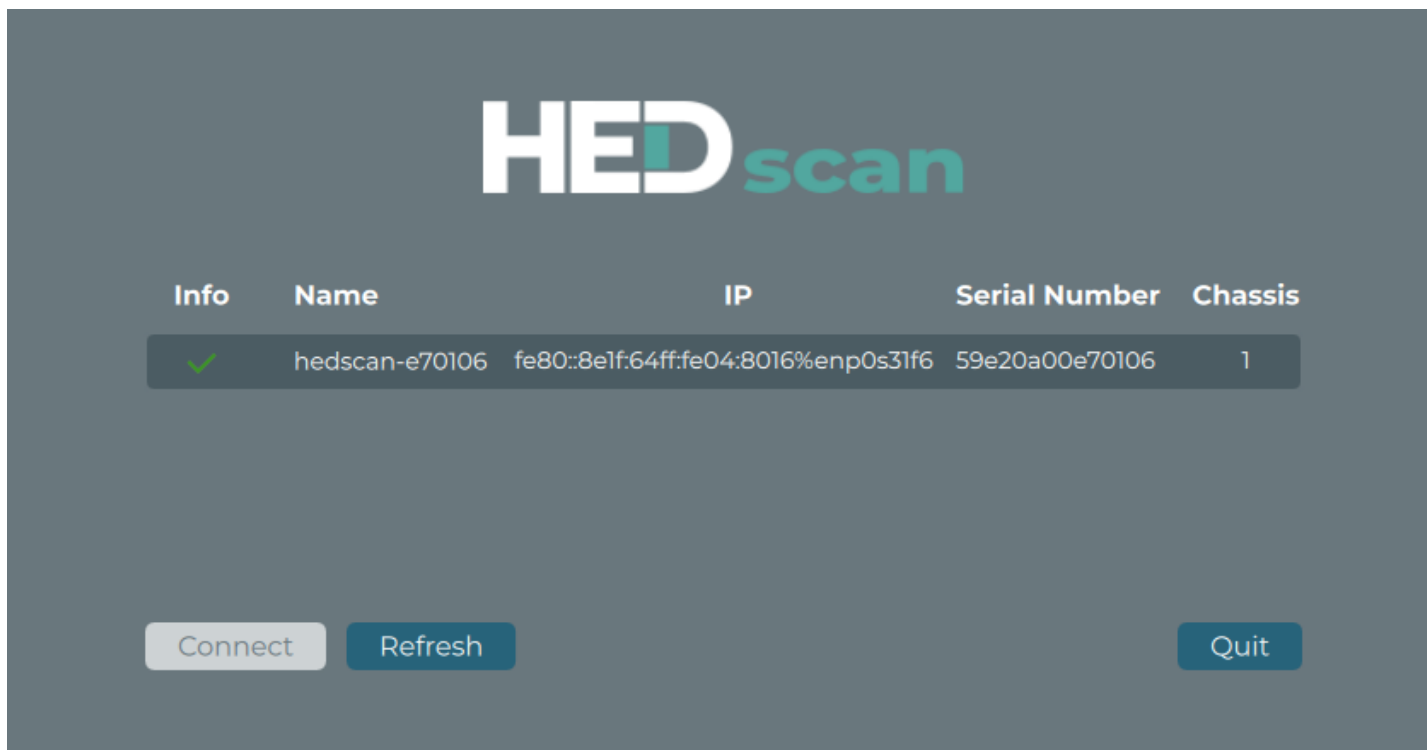


FIGURE 39 – HEDSCAN SELECT

Name – Displays the HEDscan system name.

IP – Displays the HEDscan system IP Address.

Serial Number – Displays the HEDscan serial number.

Chassis – Displays the HEDscan number of connected chassis.

Connect – Button that connects to the selected HEDscan system.

Refresh – Button that refreshes the connection dialog, searching the network to see what systems are available.

Quit – Button that exits the HEDscan system selection dialog and closes the HEDscan GUI.

HEDscan GUI Layout

The HEDscan GUI consists of multiple sections that perform different system functions. Figure 40 shows the “Chassis View” and Figure 41 shows the “2D View”. Each of these views can be broken into four parts:

- Banner
- Header
- View
- Footer

The “View” section is the only part of the GUI that will change based on selection. Each section is identified on Figure 40 and Figure 41.

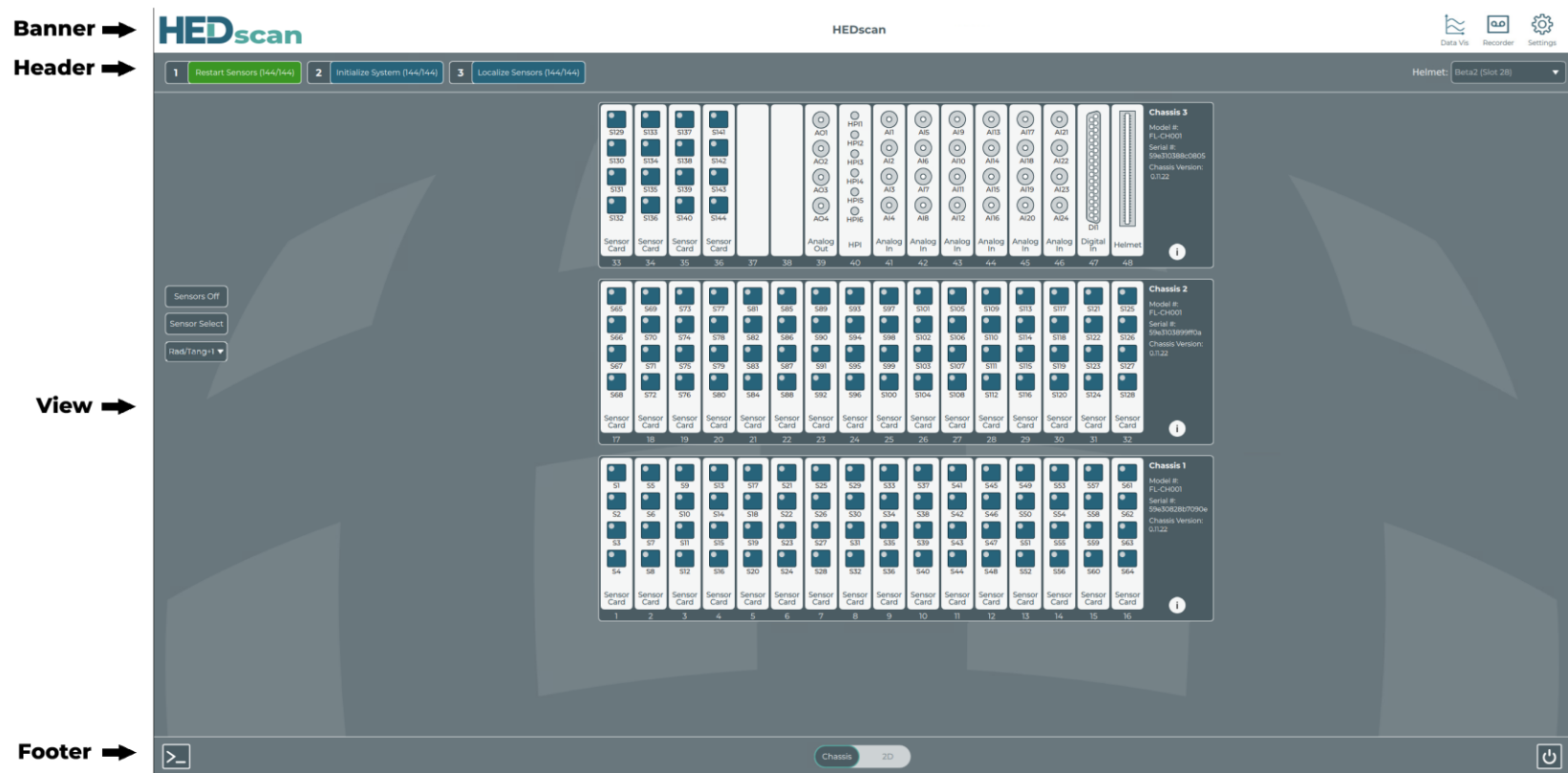


FIGURE 40 - CHASSIS VIEW LABELED

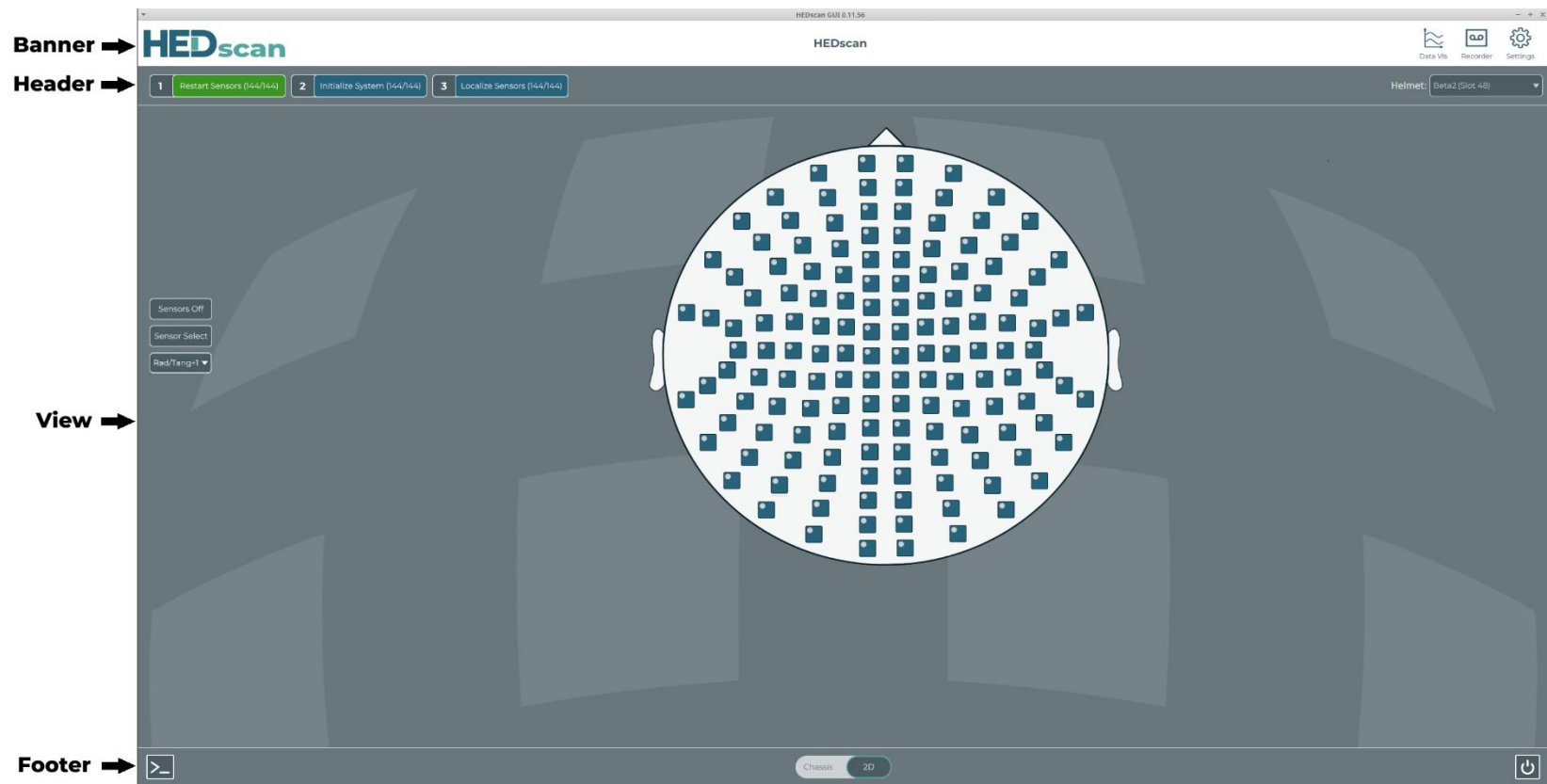


FIGURE 41 - 2D VIEW LABELED




Banner

The HEDscan Banner can be found on the top of all HEDscan windows and is the primary method for a user to open the Data Visualizer, Recorder, and Settings Menu. In the center of the Banner the “System Name” is prominently displayed (this name can be changed in the settings).

HEDscan Icons

The three icons selectable on the HEDscan Banner are detailed in Table 2. Selecting either the Recorder icon or the Settings icon will either open the window or bring a previously opened window to the foreground. Selecting Data Vis will open a new Data Visualizer window.

TABLE 2 – HEDSCAN ICONS

ICON	Description
 Data Vis	Selecting this icon will open the Data Visualizer. Icon in the upper right indicates how many Data Vis windows are open.
 Recorder	Selecting this icon will open the recording dialog.
 Settings	Selecting this icon will open the Settings dialog.

Data Visualizer

The Data Visualizer (Data Vis) displays the selected OPM and accessory card data (Figure 42). Multiple Data Vis windows (max of 8) can be opened (the number of open windows is displayed in a small circular count above the Data Vis icon). The Data Vis window consists of a primary window demonstrating a time series data plot. This plot can display multiple channels, including magnetometer data (Bz [Radial] and By [Tangential] in base units of Tesla), analog input and output data (in base units of Volts), digital input (unitless), and HPI input and output (in units of Amps). Additionally, a user can right click a stream on the Data Vis window and mark it as “BAD”.

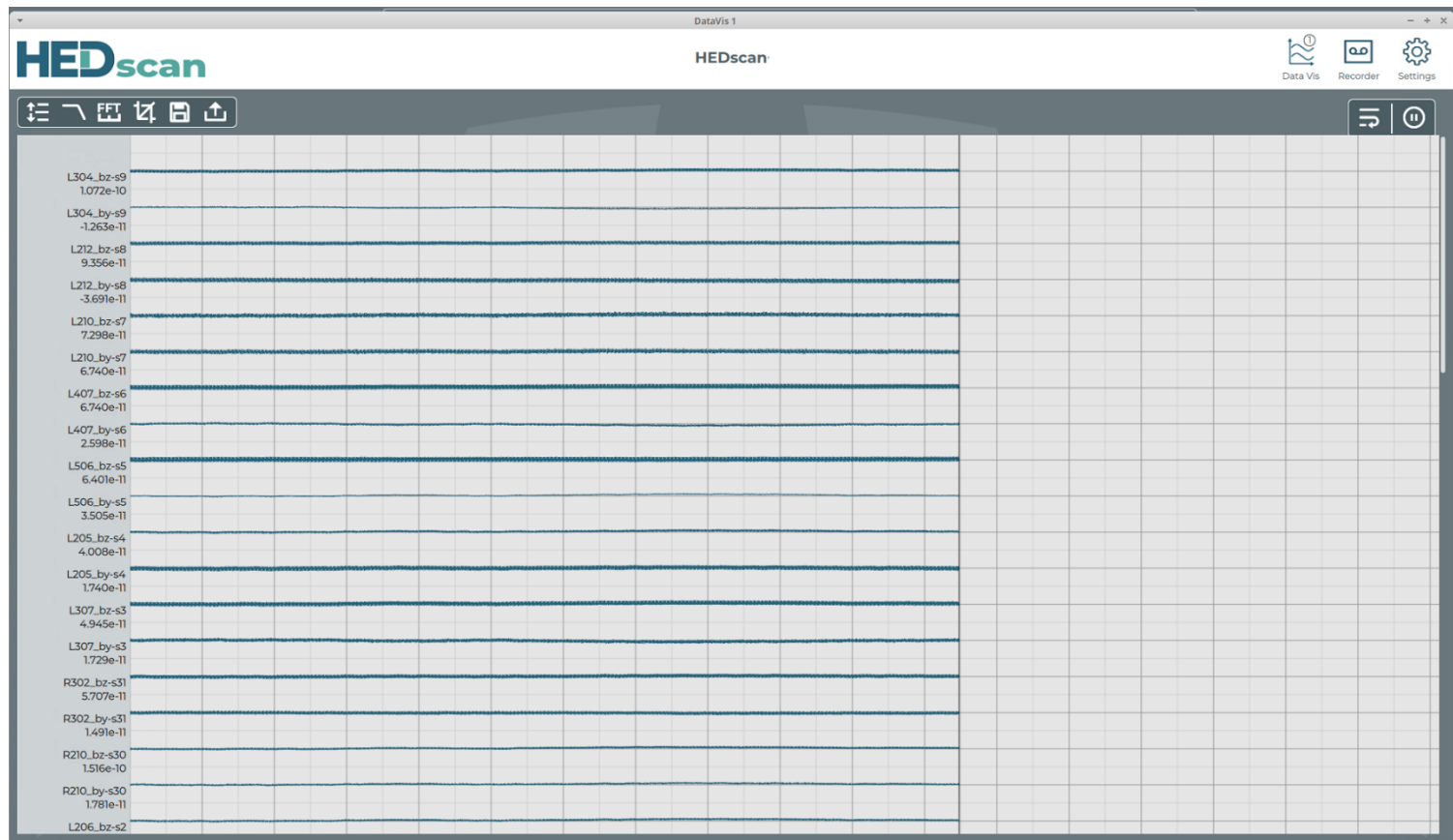










FIGURE 42 – DATA VISUALIZER

The icons on the Data Visualizer are shown and detailed below:

TABLE 3 – DATA VISUALIZER ICONS

ICON	Description
	Opens the channel select dialog
	Opens the Filter Dialog. See Filters.
	Opens the FFT visualizer. See FFT.
	Opens the Axis Settings
	Allows the user to save an FFT configuration.
	Allows the user to load a saved FFT configuration.
	Selecting this icon will toggle the display mode sweep to scroll.
	Pauses the data.

CHANNEL SELECT

The Channel Select dialog (Figure 43) allows for selection of the specific channels available in the Data Vis.

- “Available Channels” – Lists all the channel types currently viewable. Clicking on “>” will expand the channel type to allow for the selection of individual channels.
- “Selected Channels” – Lists all channels currently being displayed in the Data Vis window.
 - Channels can be manually moved and manipulated by using the arrows. By individually selecting a channel (ctrl clicking allows for additional channels to be selected; shift clicking allows for multiple channels in a series to be selected) it can be moved up or down using the single carets. The double carets will move the selected channels to either the top or bottom of the list.
- “Sort” – Identify how the selected channels should be sorted.
 - “Channel Type Asc” – Sorts the channels by type ascending
 - “Channel Type Dec” – Sorts the channels by type descending
 - “Name Asc” – Sorts the channels by name in ascending order
 - “Name Dec” – Sorts the channels by name in descending order
- “Clear” – Moves all “Selected Channels” to the “Available Channels” view
- “Apply” – Apply changes to Data Vis.

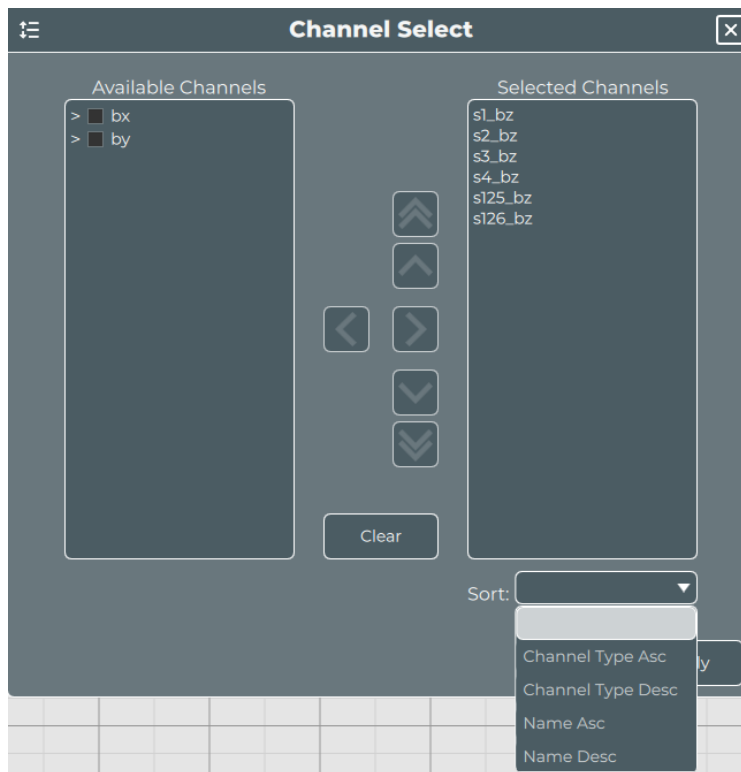


FIGURE 43 – CHANNEL SELECT DIALOG

FILTERS

Digital filters can be applied to the Data Visualizer to make it easier to identify specific patterns in the data. Select the Filter icon shown in Table 3 to open the dialog box shown in Figure 44.

NOTE: Filters applied are specific to the active Data Vis window and do NOT affect data being recorded.

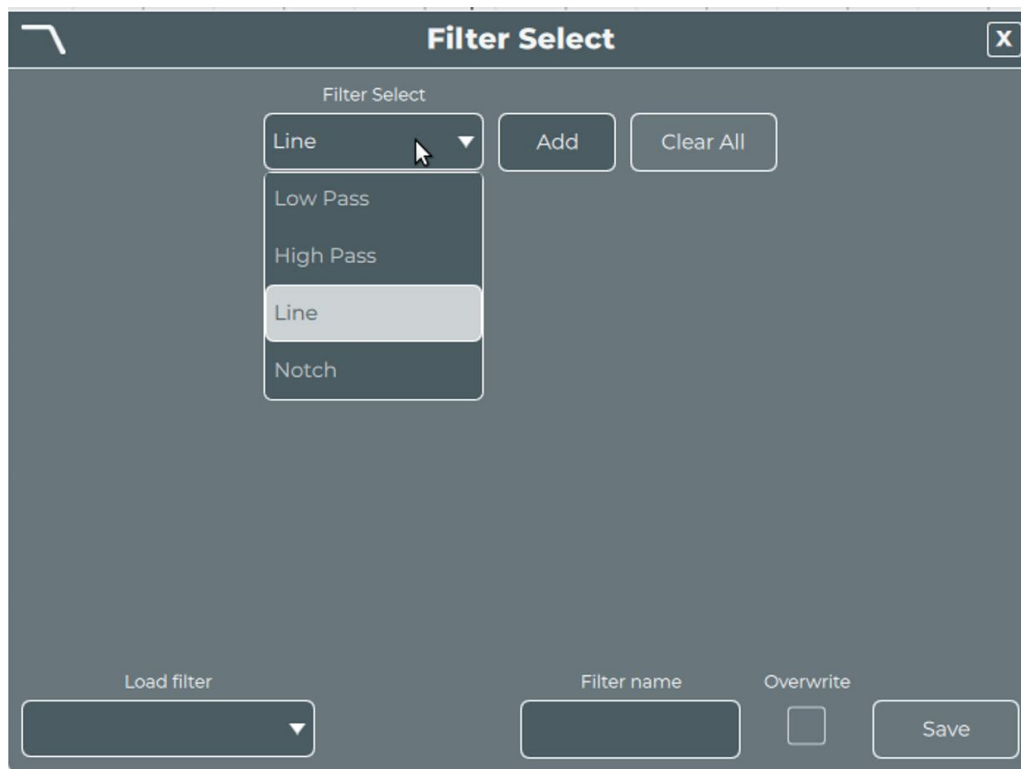


FIGURE 44 - FILTER SELECT DIALOG

Selecting on the “Filter Select” dropdown gives the option to enable one of four possible filters. These include:

- Low Pass: Attenuates signals above a chosen cutoff frequency.
- High Pass: Attenuates signals below a chosen cutoff frequency.
- Line: Special notch filter to reduce the impact of the power line frequency (on the 2nd and 3rd harmonics as well) on the data.
- Notch: User can select a specific frequency, and frequency delta to notch out of the data.

It is possible to enable up to 10 filters at a time per Data Vis window. The filters are specific to the Data Vis window. Once a filter has been selected the user can choose which channels the filters are applied to. Currently only Bz, By, Ain, Aout, and All are options.

After selecting the channel, the filter parameters can be configured.

Available filter types are Butterworth or Chebyshev. Figure 45 demonstrates how the dialog will appear once the filters have been selected and configured.

Filter Select

Filter Select

Line

Add

Clear All

Low Pass	Channel	Cut Off Freq [Hz]	Type	Order		
	Bz	100	Butterworth	4	<input checked="" type="checkbox"/>	
Notch	Channel	Fn [Hz]	Δf [Hz]	Type	Order	
	Ain	150	5	Butterworth	8	<input checked="" type="checkbox"/>
Line	Channel	Line Freq [Hz]	Type	Order		
	All	50	Butterworth	8	<input checked="" type="checkbox"/>	

Load filter

Filter name

demo

Overwrite

Save

FIGURE 45 - CONFIGURED FILTER DIALOG

Once a filter has been configured the enable toggle will allow the filter to be toggled on and off. To remove a filter select the trash icon. To save a configuration enter the desired name under “Filter name” and hit save. To reapply those filters in the future simply use the “Load filter” drop down menu.

FFT

An FFT of any of the stream types can be viewed by selecting the FFT button. Multiple Data Vis windows can be opened to view the FFT with different configurations. Additionally, a user can hover over the FFT and view the individual channels' information dynamically. A user can also right-click and mark a channel as bad from the FFT.

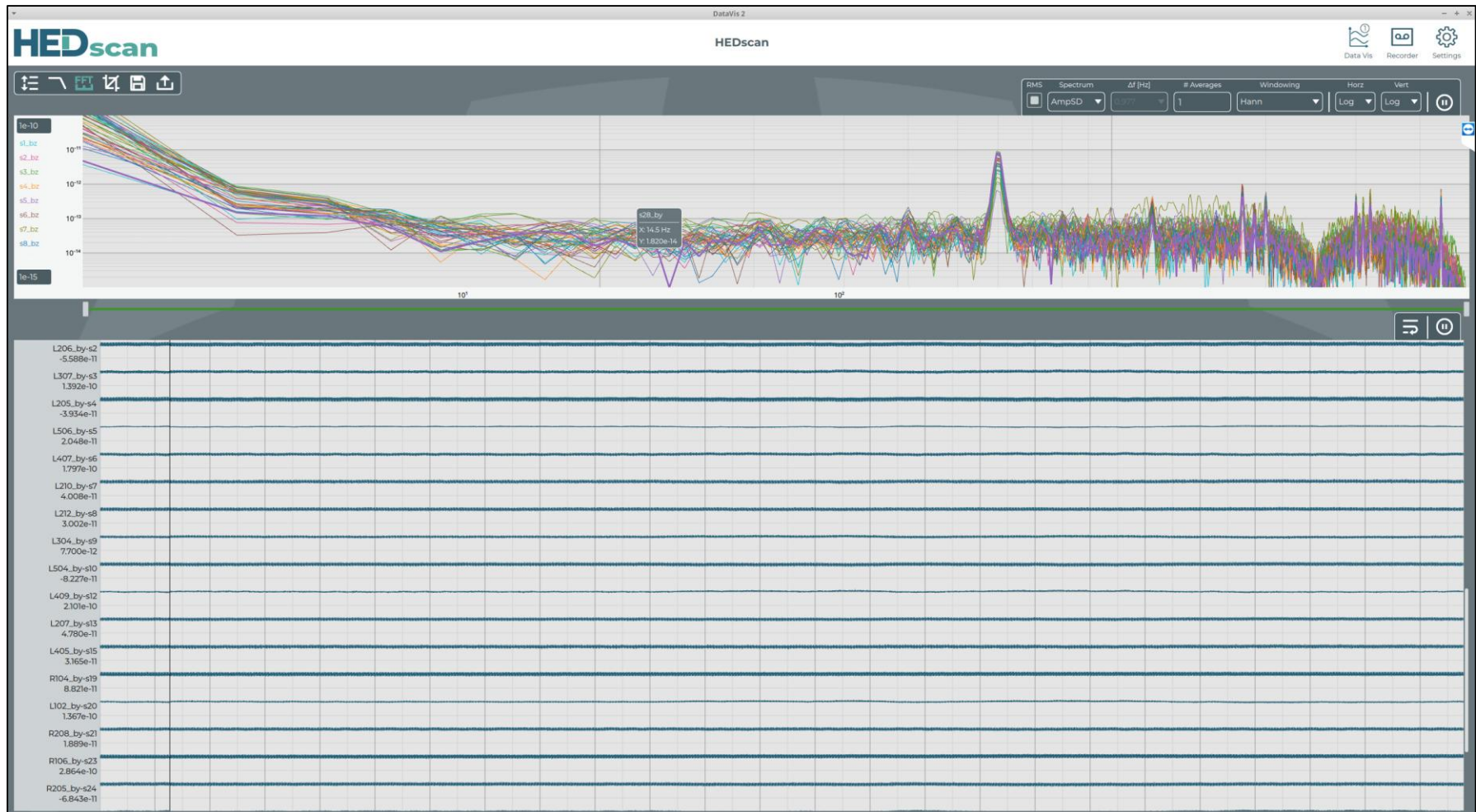


FIGURE 46 – DATA VISUALIZER – FFT

The FFT can be configured by the bar on the upper right hand of the screen. Details of each option are listed below:

- RMS – Displays the FFT in root mean squared (RMS).
- Spectrum – Sets the FFT spectrum scaling mode:
 - AmpSpec – Amplitude Spectrum
 - PowSpec – Power Spectrum
 - AmpSD – Amplitude Spectral Density
 - PowSD – Power Spectral Density
- Δf – Frequency bin size in Hz
- # Averages – Number of FFTs to average
- Windowing – Varying FFT windows
 - Hann
 - Hamming
 - Blackman
 - BlackmanHarris
 - Flattop
 - Boxcar (aka no window)
- Horz – Sets the horizontal axis to Logarithmic or Linear
 - Can adjust the scale using the green slide box underneath the window
- Vert – Sets the vertical axis to Logarithmic or Linear
 - Can adjust the maximum and minimum vertical scale using the two boxes on the left of the window
- Play / Pause the window

AXIS SETTINGS

The Axis Settings dialog allows for the configuration of the vertical and horizontal axis for the Data Visualizer. Figure 47 shows the dialog. Once configured the settings will be remembered the next time the Data Visualizer is opened.

- “Vertical Axis”
 - Graph Spacing – Effects how far apart the channels are spaced in relation to the major grid lines
 - Major Grid Delta – Adjusts the distance between the major grid lines (this does not affect the scale only the visual perspective)
 - Major Grid Enable – When selected the major gridlines are visible
 - Minor Grid Enable – When selected the minor gridlines are visible
 - Major Grid Scaling – Lists the channels currently in the Data Vis window and their respective scale factors.
- “Horizontal Axis”
 - Time [sec] – Changes the time scale of the Data Vis window.
 - Major Grid Enable – When selected the major gridlines are visible
 - Minor Grid Enable – When selected the minor gridlines are visible

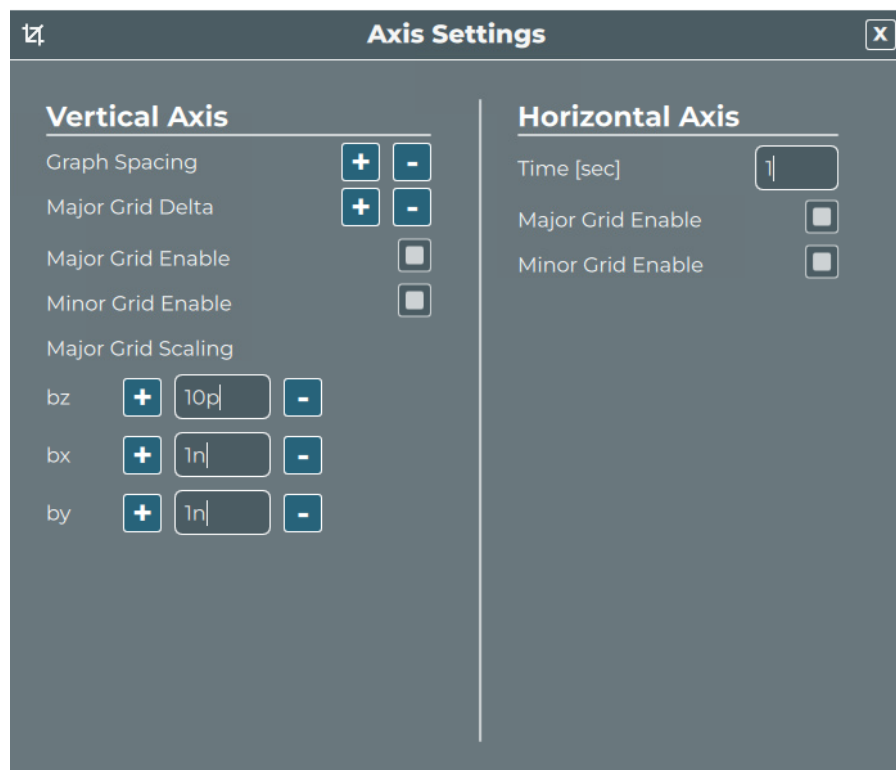


FIGURE 47 - AXIS SETTINGS DIALOG

HEDscan Recorder

Selecting the record icon opens the HEDscan Recorder seen in Figure 48. HEDscan records data using a “fif” file format. The HEDscan Recorder is split into two parts:


- File/User Information
- Recording Controls



FILE/USER INFORMATION

There are currently five fields in the File/User Information section of the recorder:

- Folder [Required]: Specifies where on the system recordings are being saved. Selecting the folder icon will open a dialog and allow the user to specify the path to the recordings.
- Project Name [Required]: Specifies the project the recording will be placed under. A folder will be generated if it does not already exist (based on the path provided in the folder section).
- Subject ID [Optional]: Specifies the subject being recorded (if no value is inserted here the default of “none” is inserted).
- Operator [Optional]: Specifies the operator of the system and will be recorded in the *.fif file metadata.
- File [Required]: Name of the recording taking place.

Recorder

 HEDscan

 Data Vis  Settings

Project Name

Example

Date/Time

2025-11-01 10:55:35

Subject ID


PolystyreneHead

Operator

TM

Folder

/home/administrator/HEDscan/recordings/hpipphantom/test



File

example

Recording Type

Time [sec]

Timed

120

Localize Head

☐ Bypass Head Localization

Record

Elapsed Remaining

-- : -- -- : --

Recording without head localization!

FIGURE 48 - DEFAULT RECORDER

RECORDING CONTROLS

The HEDscan recorder allows three types of recordings (Figure 49):

- Untimed: Will record until stopped by user
- Timed: Will record until timer elapses OR stopped by user.
- Epoch: Will record until epoch count has elapsed OR stopped by user.

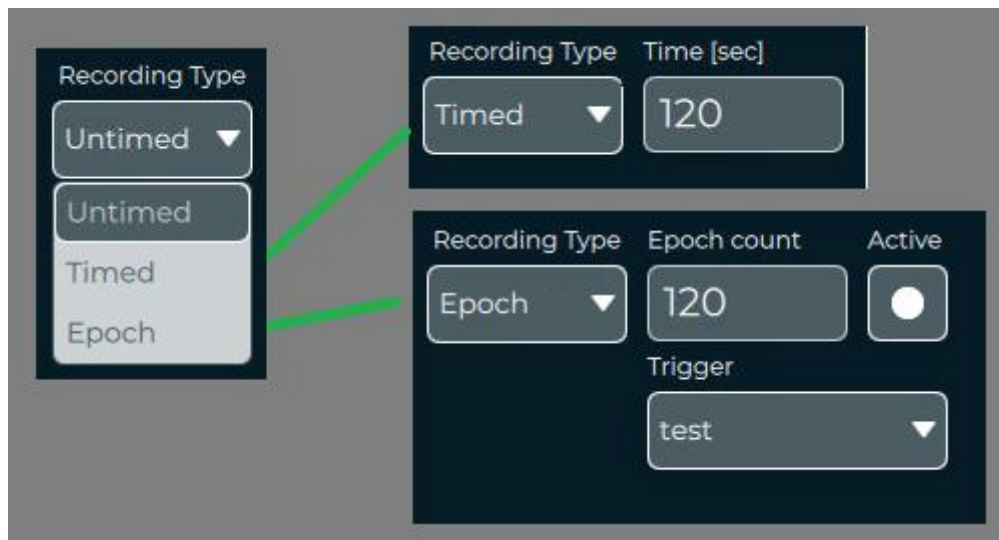


FIGURE 49 - RECORDING TYPES

After selecting a recording type, the user can choose to either require “Head Localization” or to bypass it. If “Bypass Head Localization” is not selected the “Record” button will not be available until the head has been localized (top of Figure 50).

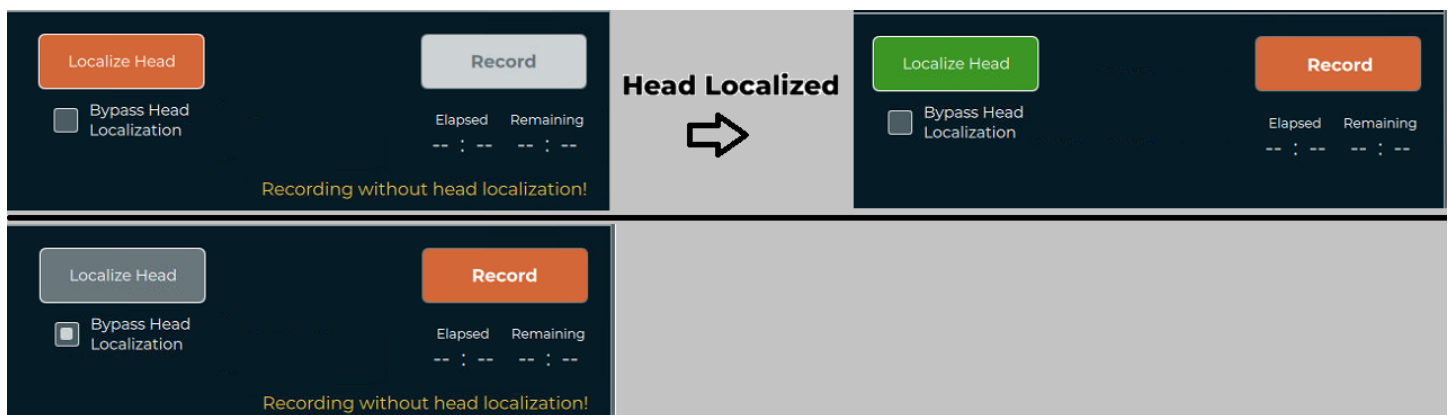


FIGURE 50 - RECORDING PATHS

The system provides two warnings for users (Figure 51) if they have not run sensor localization or if they have not localized the head:



FIGURE 51 - RECORDING WARNINGS

If a user attempts to record without sensor localization (when a smart helmet is connected) they will also observe the following pop-up warning (Figure 52):

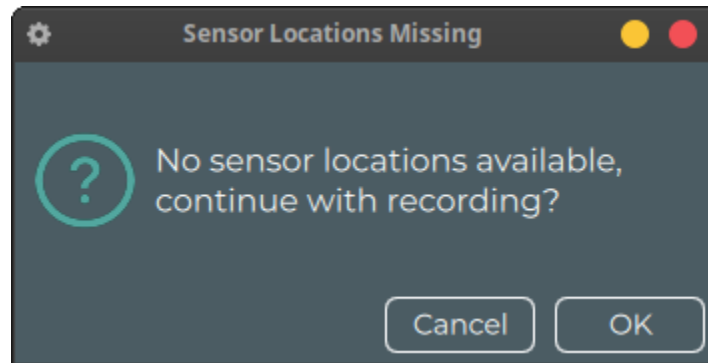





FIGURE 52 - NO SENSOR LOCALIZATION


Figure 53 shows the recorder actively recording data. Notice that the elapsed recording time is shown in the HEDscan Banner. This will be visible on all HEDscan windows. To stop an active recording select the “Stop” button.

Recorder

 HEDscan

 0:04

 Data Vis

 Settings

Project Name

Example

Date/Time

2025-11-01 10:56:43

Subject ID


PolystyreneHead

Operator

TM

Folder

/home/administrator/HEDscan/recordings/hpipphantom/test



File

example

Recording Type

Time [sec]

Timed

120

Localize Head

☐ Bypass Head Localization

Stop

Elapsed Remaining

00:04 01:56

FIGURE 53 - ACTIVE RECORDING

Settings Dialog

The settings dialog allows the user to control, configure, and update the HEDscan system.

SYSTEM TAB

The system tab (Figure 55) allows the user to configure the following:

- **System Name:** Type a name in the option box and hit apply to give the system a name. In the example the system name is “HEDscan”. Hitting reset will clear the name to the default system name of “hedscan-XXXXXX” where XXXXXX are the last 6 digits of the serial number. Having a name will allow the system to boot faster.
- **Diagnostics:** Can be collected by selecting the “Generate” button. If an error or odd behavior with the system occurs during operation, selecting the generate diagnostics button will create a *.tar.gz file that can be sent to FieldLine Medical for analysis.
- **Disk Utilization:** To avoid the loss of data the HEDscan-GUI monitors disk utilization. If the disk utilization is over 80% a warning (Figure 54) will pop up to notify the user there is potential for data loss due to insufficient space.

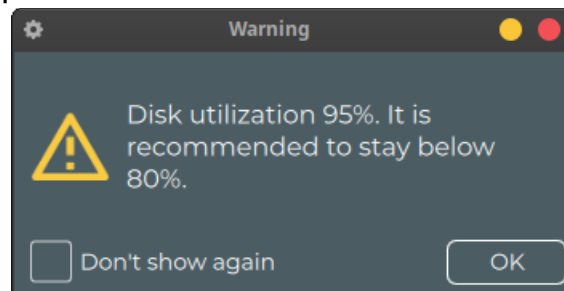


FIGURE 54 - DISK UTILIZATION

- **Warnings:** Clicking this button will reset all warning pop-ups. For example, if the “Don’t show again” box is selected on the image in Figure 54, the pop will cease to appear until warnings are reset. FieldLine Medical recommends leaving warning pop-ups in place.
- **System Cache:** Clicking this button will clear the cached 2D View and any sensor that has been excluded or marked as bad. Disconnect and reconnect to apply the change.

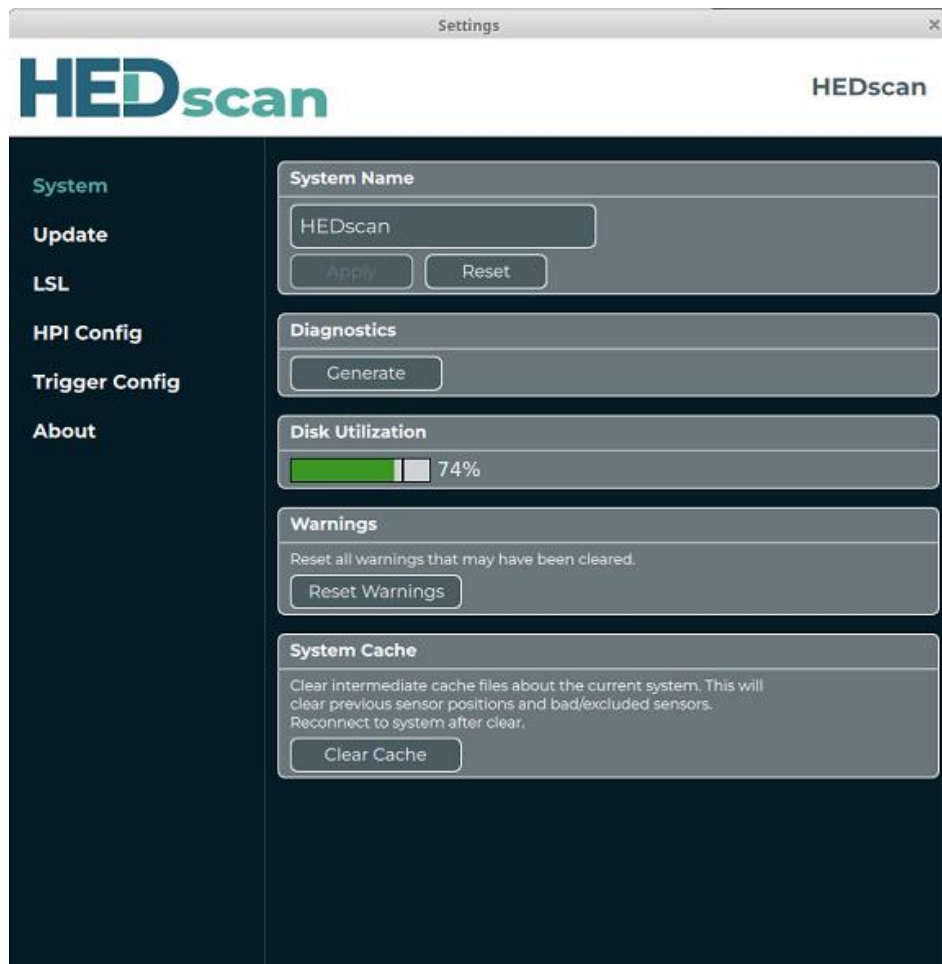


FIGURE 55 - SETTINGS (SYSTEMS TAB)

UPDATE TAB

The Update Tab (Figure 56) allows the user to configure the following:

- Updates: Clicking the “Update System” button will apply the latest HEDscan firmware to the system. See the “HEDscan Updates” section for more details.
- Install Parameters: When a new (or replacement) sensor or sensor card is received, it will need to have parameters installed to operate in the system. FieldLine Medical will provide a *.param file that can be uploaded under the “Install Parameters” option. Upload the file and select install. The filename field will then clear, and the Console will display a message when the installation is complete.



FIGURE 56 - SETTINGS (UPDATE TAB)

LSL TAB

Other programs can access the HEDscan streams in real time using the Lab Streaming Layer. Simply select “Enable LSL” to turn on or select again to turn off. (Figure 57).

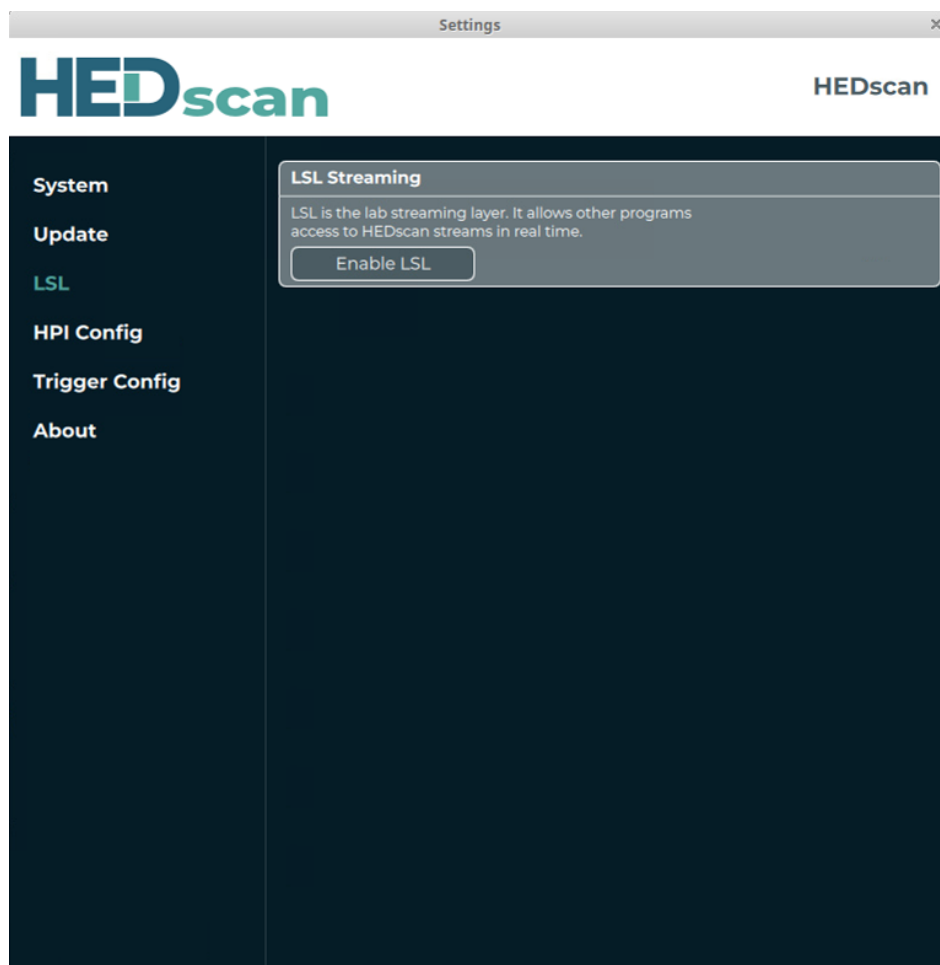



FIGURE 57 - SETTINGS (LSL TAB)

 **CAUTION:** It is impossible to add/remove streams while LSL is enabled. Doing so will cause the GUI to crash. If sensors need to be turned off, or additional streams are desired, first disable LSL.

HPI CONFIG TAB

For systems with an HPI card installed, HEDscan can perform “Head Localization”. To achieve this the first step is to configure the HPIs. The HPI Config Tab (Figure 58) has the following options to achieve this:

- **HPI Settings:** Enabling this check box will add all sensor head positions as digitization points in the *.fif file.
- **HPI Parameters:** Users can set an HPI frequency that is above 10 Hz but below 55 Hz. FieldLine Medical recommends a frequency range that is outside any vibrations naturally found on site. [NOTE: For sites with 50Hz power do not select 50 Hz as the HPI Frequency].
- **HPI Positions:** At a minimum, three HPI coils need to be identified as the “Nasion”, “RPA”, and “LPA”. Additional coils can be added (some are pre-named such as “Inion” and “Cz”, while others can be given a custom name of up to 6 characters). Users cannot name a coil one of the previous mentioned names as they are reserved.

The screenshot shows the HEDscan Settings window with the HPI Config Tab selected. The window has a dark blue sidebar with navigation options: System, Update, LSL, HPI Config (highlighted), Trigger Config, and About. The main content area is divided into three sections:

- HPI Settings:** A checkbox labeled "Use sensors as digitization points in recordings." is currently unchecked.
- HPI Parameters:** A text input field shows "23" for "HPI Frequency [Valid Range: 10-55 Hz]".
- HPI Positions:** A list of five HPI positions with checkboxes and dropdown menus:
 - HPI1: LPA
 - HPI2: Nasion
 - HPI3: RPA
 - HPI4: Inion
 - HPI5: Custom (with a text input field containing "Ex")

FIGURE 58 - SETTINGS (HPI CONFIG TAB)

TRIGGER CONFIG TAB

HEDscan systems with Analog Input or Digital Input cards can be configured to use specific ports or bits as a trigger stream. The Trigger Config Tab (Figure 59) allows users to configure these ports.

- **Analog Input:** For the analog input triggers the user must specify a unique trigger name, which analog input channel to use as a trigger, whether the trigger should occur greater than or equal to, OR less than or equal to an incoming voltage. Selecting the green check locks in the value.
- **Digital Input:** Digital triggers are set similarly to analog however the trigger conditions vary. Digital triggers are level based and can occur when the indicated bit (31:0) is high, or when the digital input matches the provided hexadecimal bit mask against the given logical operation. For example, if the condition is set to “AND” and the user sets the bit mask to 0x15, the trigger will only be set to one when digital bits 0, 2, and 4 are high.

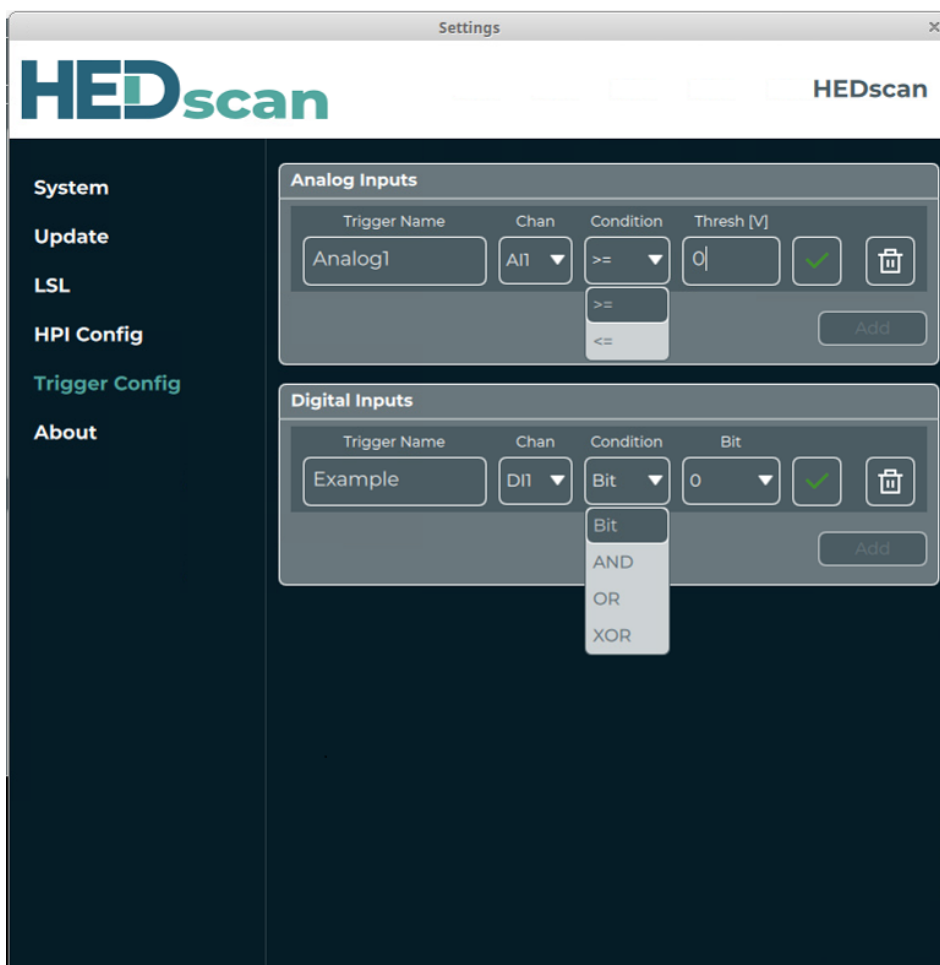


FIGURE 59 - SETTINGS (TRIGGER CONFIG)

Once the triggers are set a “Test” button appears (Figure 60). Once selected when the circle is colored green the system indicates it observes the trigger condition set by the

user. For example, in Figure 60 the system indicates that Analog Input port 1 observes a voltage greater than or equal to 0V.

Analog Inputs

Trigger Name	Chan	Condition	Thresh [V]	Test	
Analog1	All ▼	>= ▼	0	<div></div>	<div></div>

Add

FIGURE 60 - TRIGGER TEST BOX

ABOUT TAB

The About Tab (Figure 61) gives the users general system information.

- **Contact:** Provides the contact information for FieldLine Medical Support.
- **User Manual:** Selecting “Launch” will open this document locally on the system.
- **Release Notes:** Selecting “Launch” will open the “Release Notes” text locally on the system.
- **Licenses:** Provides all licenses used by the HEDscan system and software as used with permission and associated organizations copyrights.

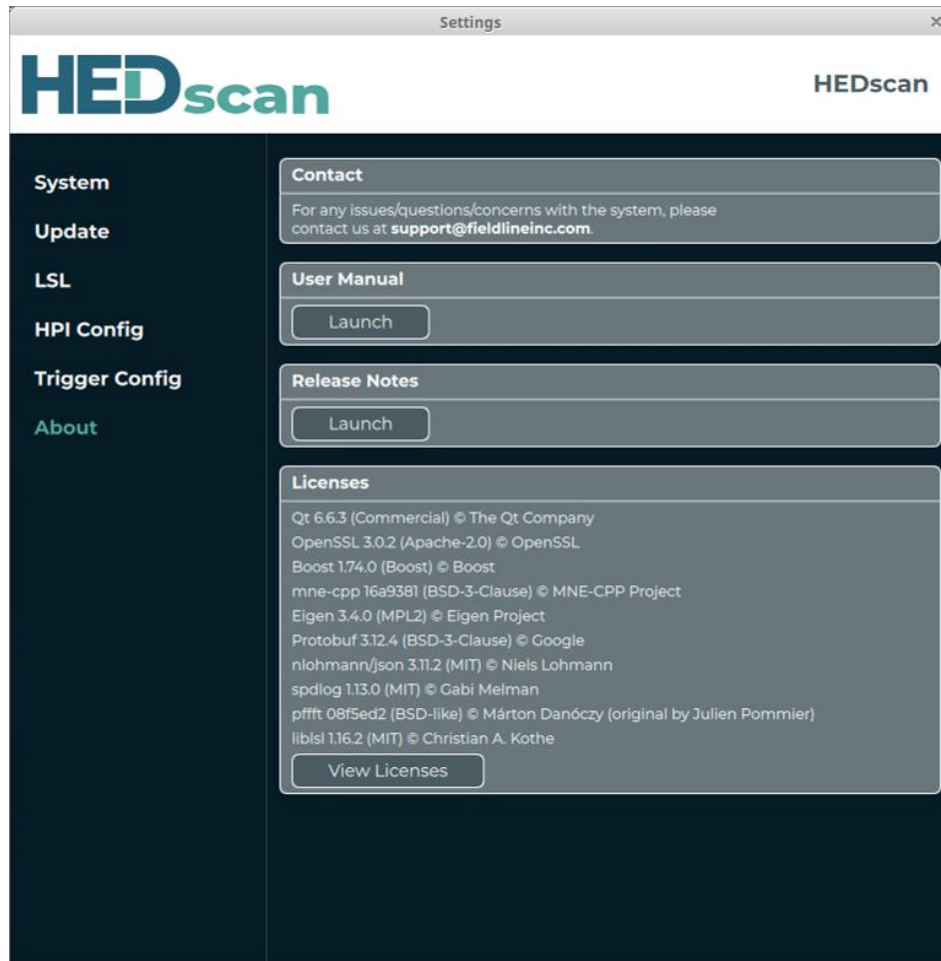


FIGURE 61 - SETTINGS (ABOUT TAB)

Header

The HEDscan Header is present in all chassis views, but is not visible in the Data Visualizer, Recorder, or Settings menu. The recorder consists of two key features:

- OPM Control Buttons
- Helmet Selection Dropdown

OPM Control Buttons

There are three buttons that can control OPMs (Figure 62). Each button has a count of how many sensors out of the total that have been either restarted, initialized or localized.

- Restart Sensors: Clicking this button will restart all selected OPMs. The button will default to Orange when sensors are off and then blink green while sensors are restarting. If an error occurs the button will be red until they are handled.
- Initialize System: Clicking this button will initialize all selected OPMs. The button is only selectable if some of the selected sensors have been restarted. Selected sensors that have not been restarted will be ignored. While initializing the button will blink blue and go solid when complete.
- Localize Sensors: Clicking this button will attempt to localize all initialized OPMs. (OPMs not located in the Smart Helmet will not be localized). The process takes less than a minute and any failures are listed in the command console.

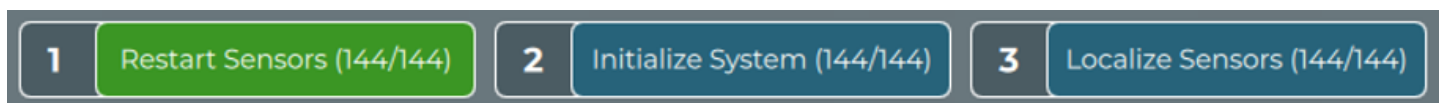


FIGURE 62 - OPM CONTROL BUTTONS

Helmet Selection Dropdown

The helmet selection dropdown will let users localize sensors on the selected helmet.

Views

The HEDscan GUI currently displays either a virtual representation of the installed system (Chassis View) or, with a smart helmet installed, a two-dimensional view of the installed helmet (2D View).

OPM Selection and Control

OPMs can be selected by either using the sensor select menu (Error! Reference source not found.) or by individually selecting the sensor. Hold ctrl to manually select multiple sensors.

SENSOR COLOR CHART

The HEDscan GUI makes use of colors to indicate the state of a sensor. Table 4 details the state of each sensor and accessory card as demonstrated by Figure 63. While the system is performing an operation it will blink the symbol.

TABLE 4 - COLOR CHART

Slot #	Accessory Type	Color	Detail
1	Sensor	Gray	No OPM Connected
2	Sensor	Orange [Solid]	OPM Connected and sensor off
3	Sensor	Orange [Line]	OPM has been excluded from sensor selection by user.
4	Sensor	Orange [B]	OPM has been marked "BAD" by user.
5	Sensor	Green [Solid]	OPM has been restarted and is ready to be initialized.
6	Sensor	Blue [Solid]	OPM has been initialized
7	Sensor	Blue [Gray Dot]	Initialized OPM has been selected
8	Sensor	Red [Solid]	OPM is in an error state
9	Sensor	Gray [Red Box]	Sensor Card is unconfigured
12	Analog Out	Blue [Solid]	Selected ports are enabled and streaming
13	HPI	Blue [Solid]	Selected port is enabled and streaming
14	Analog In	Blue [Solid]	Selected port is enabled and streaming
15	Digital In	Blue [Solid]	Selected port is enabled and streaming
16	Helmet	Blue [Blinking]	Sensor localization is occurring

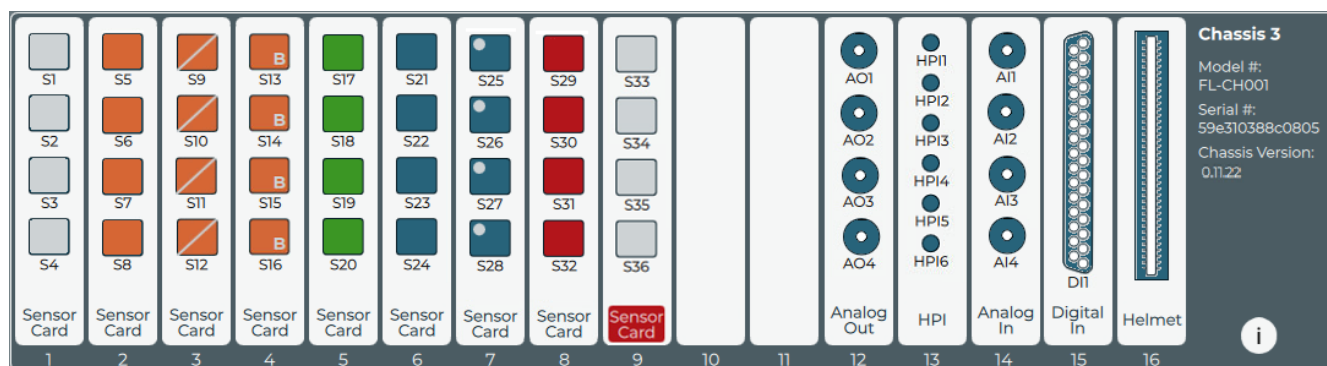


FIGURE 63 – CHASSIS COLOR CODES

SENSOR SELECTION AND AXIS CONTROL

HEDscan will only operate on selected sensors. The sensor restart and initialize commands (sent via the buttons in the upper left-hand corner of the GUI) will only affect selected sensors (indicated by the grey dot in the top left corner).

Left clicking on a sensor will select a single sensor and clear any previous selection. Holding CTRL while left clicking will toggle the specific sensor's selection state, while maintaining the selection state of all other sensors.

To quickly select multiple sensors, press the Sensor Select button (see Figure 66Error! Reference source not found.) on the left-hand side of the chassis view. The options provided are:

- Select all - selects all connected sensors
- Deselect all - deselects all sensors
- Select ■ (off) – selects all connected sensors currently in the off state
- Select ■ (restarted) – selects all connected sensors currently in the restarted state
- Select ■ (initialized) – selects all connected sensors currently initialized
- Select ■ (error) - select all sensors that are currently in the error state

NOTE: If any OPM or sensor card is marked red upon system boot-up, contact FieldLine Medical Support. These units are missing key parameters to their operation and cannot operate without them.

Right clicking on a sensor will open a context menu (Figure 64) that will affect all selected sensors.

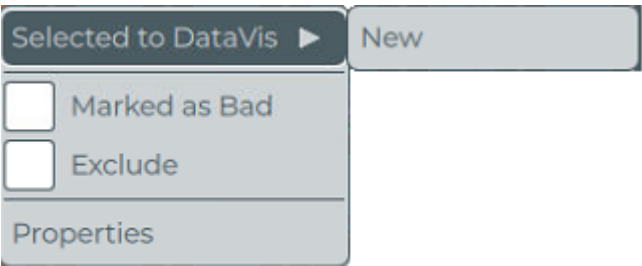


FIGURE 64 - RIGHT CLICK MENU

The options in the right-click menu are:

- **Selected to Data Vis:** selecting this option will either open a new Data Vis window with only the selected sensors OR send the selected sensors to a previously opened window (if they are not already enabled).
- **Marked as Bad:** This option will mark all sensors selected as “Bad” in the fif recording
- **Exclude:** This option will exclude the selected group of sensors. Excluding means that the system will not select those sensors even if the “Select All” option is chosen. The only way to select these sensors is intentionally clicking them or by using the “sensorselect” console command.
- **Properties:** This will open the “Properties” dialog (Figure 65). Users can observe the selected sensors serial numbers, helmet position, whether they have been marked as bad, excluded, their compensated fields, and any error codes they are currently under. This information can be exported as a csv.

Selected Sensor Properties									
Compensated [nT]									
Num	Serial	Pos	Ex	Bad	Bx	By	Bz	Error	
S1	0U7ZC3	--	--	--	--	--	--	--	
S2	0U7U6V	--	--	--	--	--	--	--	
S3	0U7WSV	--	--	--	--	--	--	--	
S7	0U7Z8F	--	--	--	--	--	--	--	

FIGURE 65 - SENSOR PROPERTIES

The “Sensors Off” button applies to all selected sensors (Figure 66) and will power the OPM off.

There is also a sensor selection menu that provides additional sensor select options. The options are expanded in 2D view (to the right) to select specific regions of the brain.



FIGURE 66 - SENSOR SELECT MENU

Additionally, there is an option to change the sensitive axis of the magnetometer. The button below “Sensor Select” displays the currently designated sensitive axis. When clicked it displays the following three options (Error! Reference source not found.Figure 67):

- Rad/Tang+1 [Radial + Tangential (2+1 Axis)]
- Rad/Tang [Radial + Tangential (Dual Axis)]
- Rad [Radial (Single Axis)]

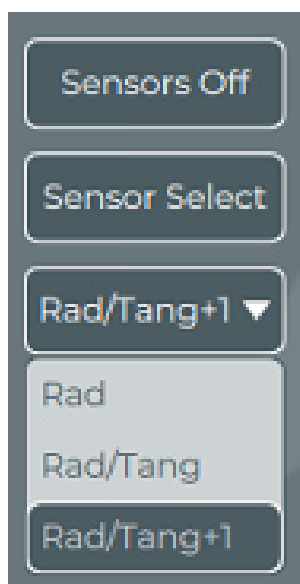


FIGURE 67 – SENSITIVE AXIS MENU

Previously the sensitive axis was called Bz indicating the radial axis, with By indicating the tangential axis. Currently in the *.fif recordings the channels are still indicated as Bz and By. Additionally, the “+1” nomenclature refers to Bx being actively compensated at a reduced bandwidth.

NOTE: OPMs must be specifically configured to operate in multi-axis mode. Contact FieldLine Medical Support to tune sensors.

Chassis View

The primary view for command and control is the “Chassis View” and it is the only way to interact with accessory cards that do not drive OPMs. If there is a gap in accessory cards the numbering will continue at the next slot. Notice in Figure 68 that the sensor card number from chassis two to chassis three shows no gaps between numbers.

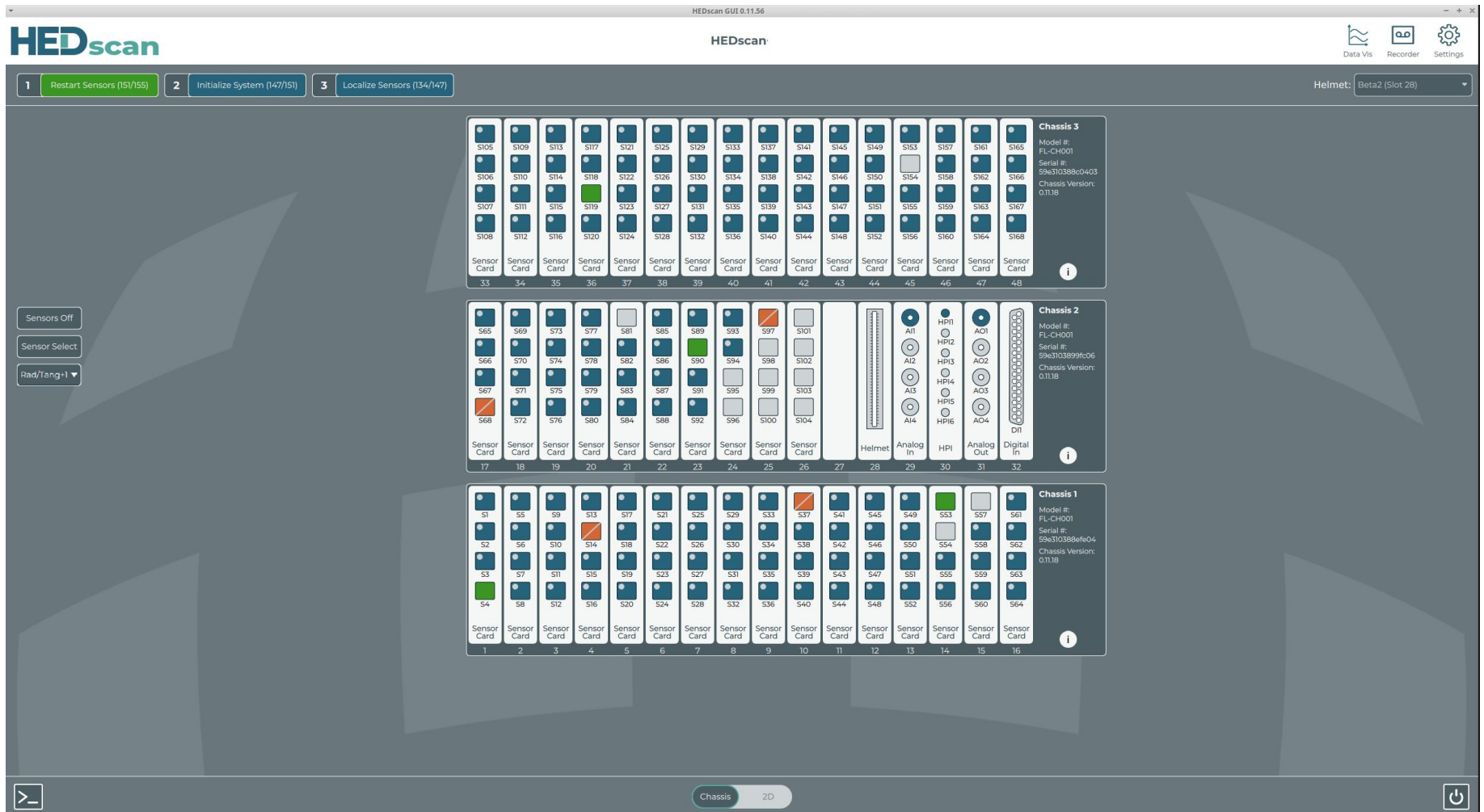


FIGURE 68 - CHASSIS VIEW

2D View

When a Smart Helmet is installed the 2D View option will be available (Figure 69). This view allows the user to visualize the sensors as they are localized on the helmet. The GUI saves the most recent localization results and continues to display them in the 2D view even when the sensors have not been re-localized. If a sensor is moved without being re-localized the sensor will remain at its previous location. Figure 69 demonstrates this by showing a few sensors that have been restarted but not localized (green).

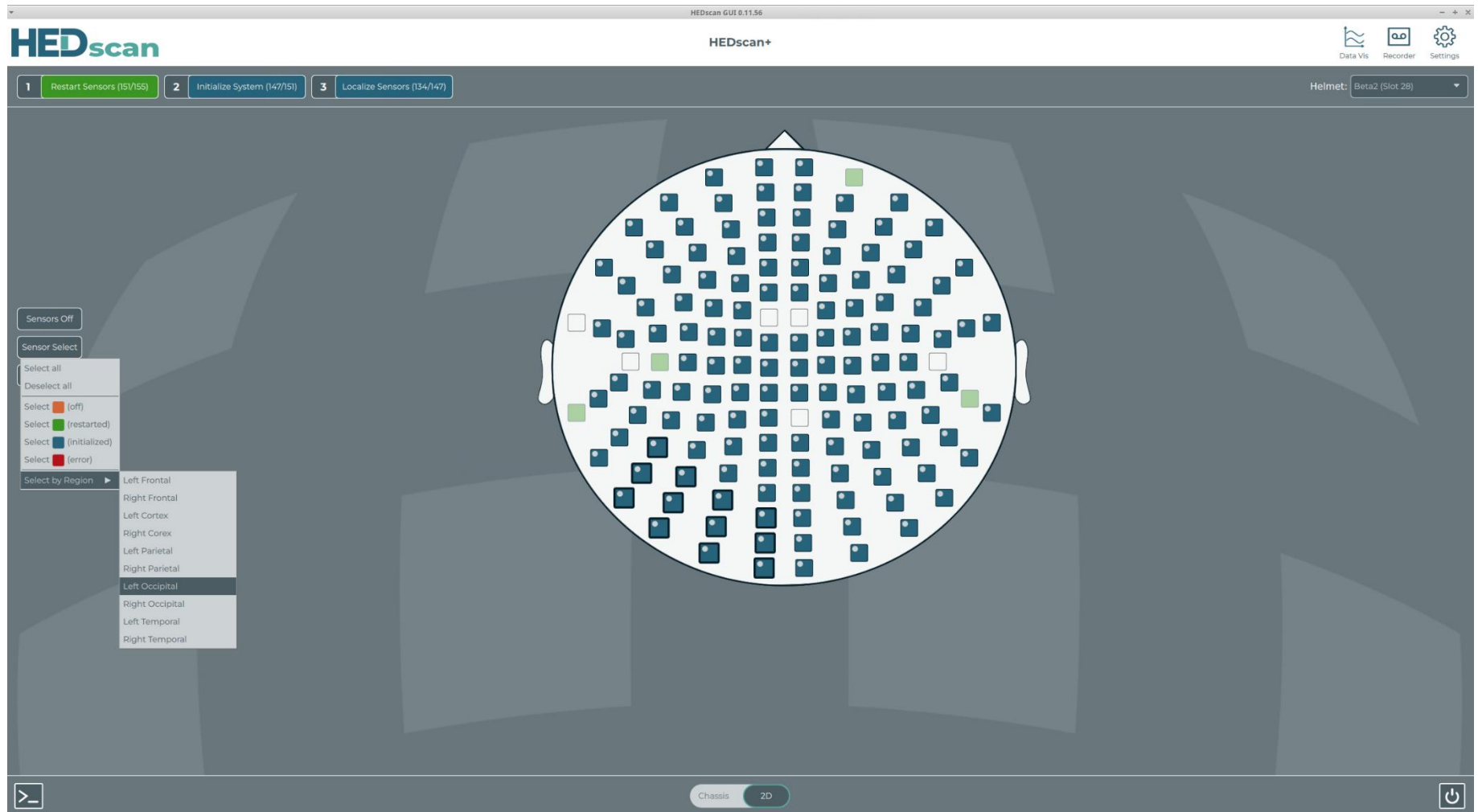


FIGURE 69 - 2D VIEW

Figure 69 also demonstrates the system highlighting a region (in black border) when selecting by region. Figure 70 demonstrates 2D View where the sensors are off. HEDscan caches the locations of sensors that were previously localized at their last known location and indicates the location is an estimate by using a lighter color shade.

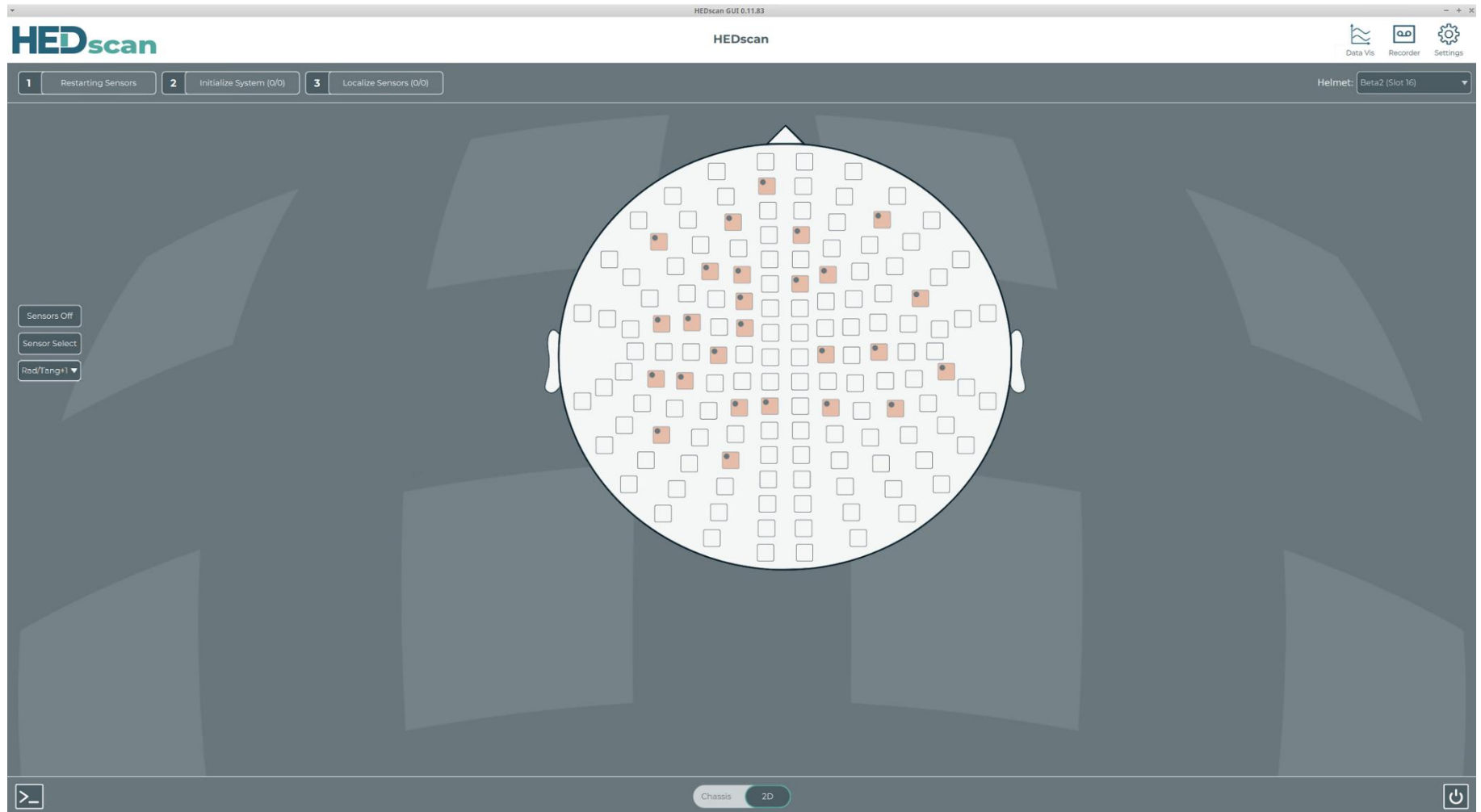


FIGURE 70 - 2D VIEW SENSORS OFF

Figure 71 demonstrates sensors that have been initialized (and previously localized) but not re-localized in 2D View:

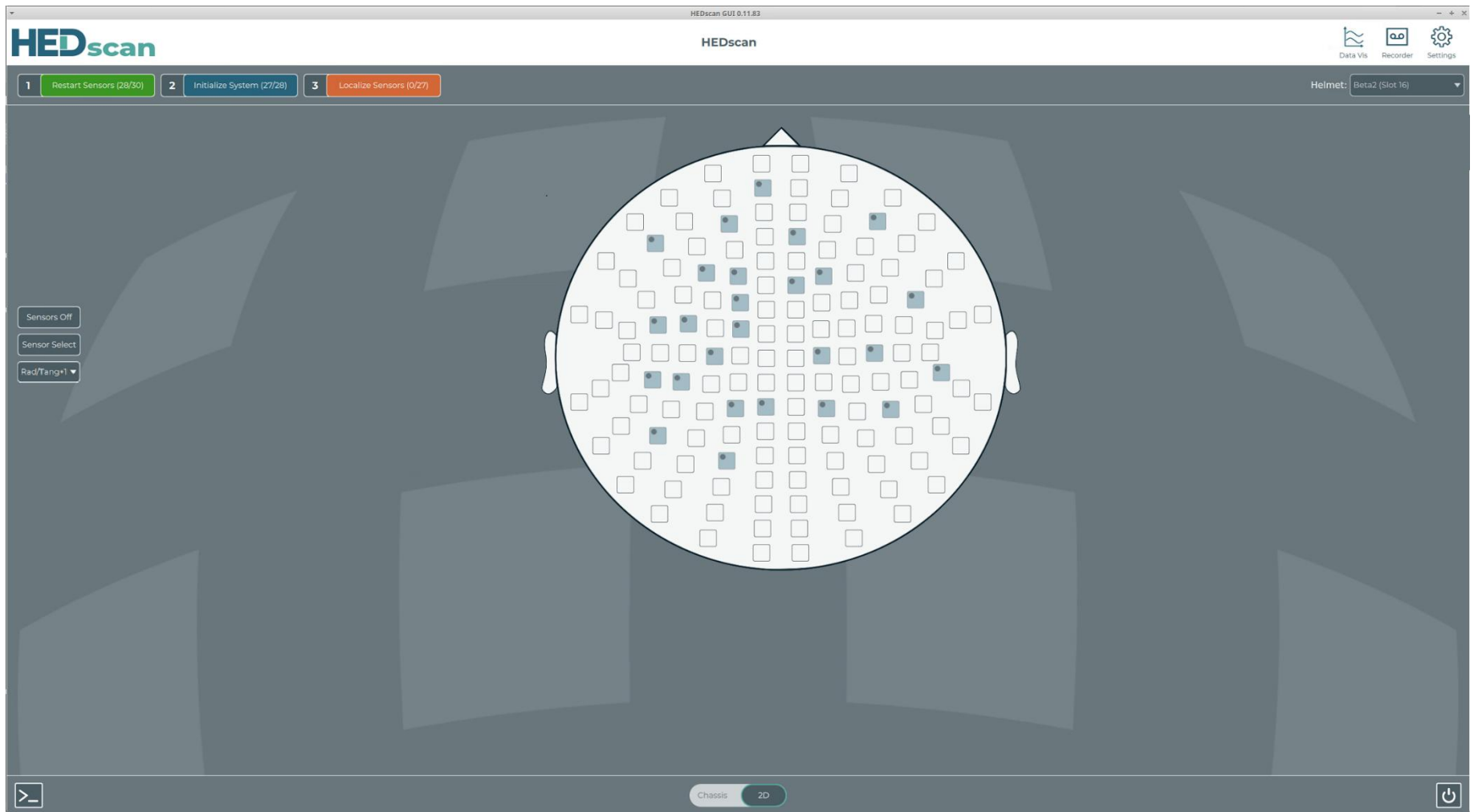


FIGURE 71 - 2D VIEW INITIALIZED

Footer

The final section of the HEDscan GUI is the footer which includes the following components:

- Console Command
- View Toggle
- Power Options

Console Commands

The HEDscan GUI can send specific console commands to control the system. Users can enter console commands via the command window or can run a custom script to send multiple commands at once. Sensor run time information can also be observed in the console. Occasionally if a sensor experiences an error condition, an error code will appear. Sharing these error codes is useful for support contacts with FieldLine Medical.

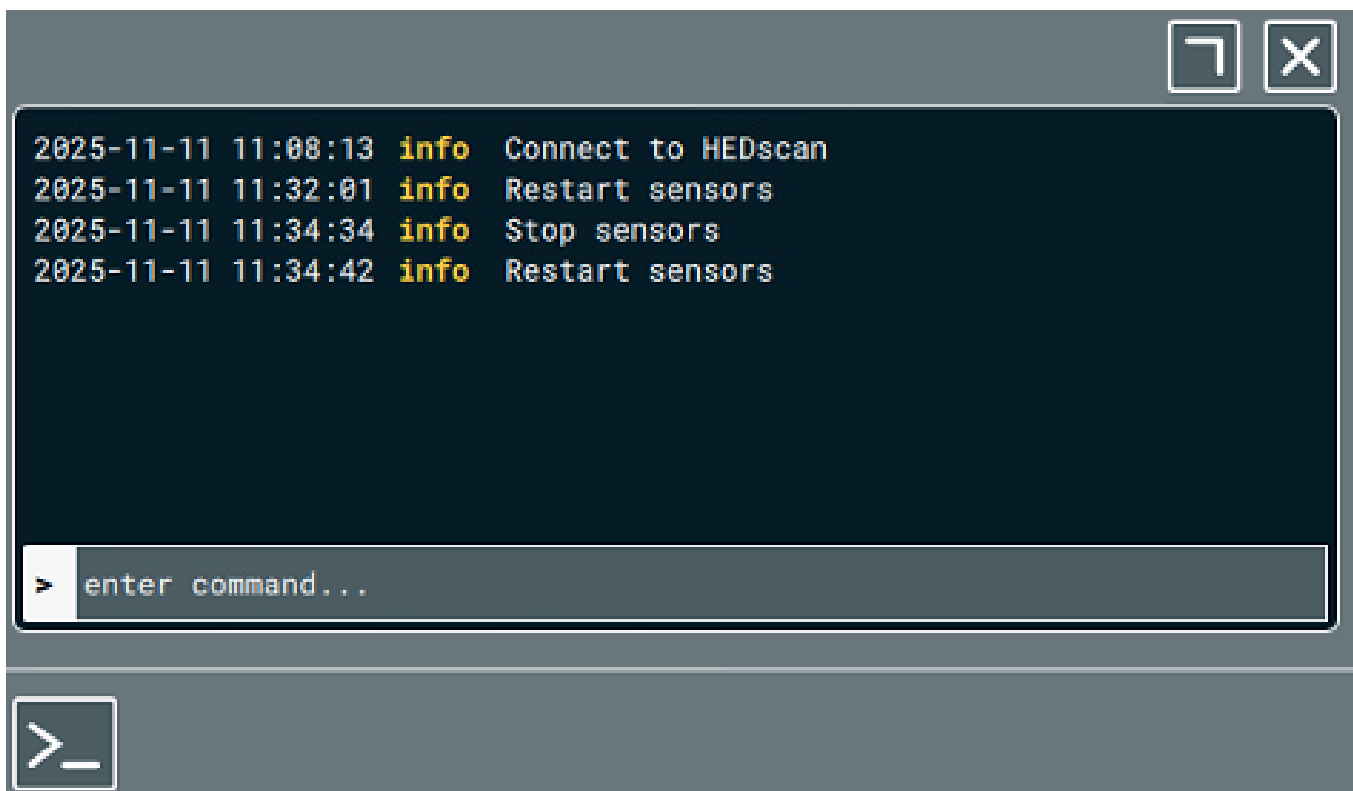


FIGURE 72 – CONSOLE

Below in the described console commands the following value is used:

<selection string>

The selection string is either the value “selected” or a comma separated list of individual numbers or number ranges. If the value “selected” is inserted the command sent will be applied to all sensors currently selected on the GUI. An example of the comma separate list is below:

1,2,4-7

Additionally, the selection string can be replaced with a * that will select all available objects. If desired, in place of the selection string, the string “selected” can be used to have the console act upon all sensors currently selected in the GUI.

The available console commands are:

```
sensorselect <selection string>
```

```
sensorselect clear
```

sensorselect allows the user to rapidly select and deselect OPMs.

```
streamctl ls
```

```
streamctl <enable|disable> <stream type> <selection string>
```

streamctl allows the user to enable and disable specific stream types. The stream types the user can enable or disable are found using the **streamctl ls** command.

```
truefield <enable|disable>
```

truefield allows the user to swap between looking at the magnetometer true field (background plus detected field) vs the zero-field value (detected field). Note that the values included in the *.tsv file generated with each recording lists the DC fields in nT. If truefield is enabled these DC fields are added to the measured magnetic field to show the total field in the room.

```
wavegenctl <wavegen num> -s <shape> -f <frequency> -p <phase> -a  
<amplitude> -d <dc offset> -t <pulse delay> -c
```

wavegenctl allows the user to set the type of function applied to either the analog or HPI output. Except for <wavegen num>, all the following arguments are optional.

- -s sets the shape of the applied function. The available shapes are [types can be abbreviated by the portion in the square brackets]:
 - [dc]
 - [sq]uare
 - [saw]tooth
 - [tri]angle
 - [sin]e
 - [cos]ine

- [trng] (true random number generator)
- -f is a floating-point number that sets the frequency in Hz. The highest possible frequency is 125kHz. However, it is not recommended to go higher than 25kHz. The accuracy of the triangle wave begins to decrease when the frequency is above 10kHz.
- -p is a floating-point number that sets the phase of the waveform in degrees from 0 to 360.
 - NOTE: The phase is only applied to sine and cosine functions.
- -a is the floating-point number that sets the amplitude of the waveform in volts from $\pm 10V$.
- -d is the floating-point number that sets the DC offset of the waveform in volts from $\pm 10V$.
 - NOTE: The waveform will clip at $\pm 10V$ if the signal goes out of range.
- -t is the floating-point number that sets the pulse delay.
 - NOTE: Pulse delay is only applicable to wavegen num 1 through 4.
- -c will clear the current configuration. If used in conjunction with any of the above flags it will clear the previous settings and then apply those flags.

wavegenreset

wavegenreset will restart all waveforms at time 0 allowing for synchronization of the applied functions. Whenever a frequency is changed on a waveform it will no longer be synchronized with any of the other wavegens.

aoutctl <aout num> wavegen <selection string>

aoutctl allows the user to specify which port the analog data will be applied to.

hpictl <hpi num> wavegen <selection string>

hpictl allows the user to specify which port the analog data will be applied to.

NOTE: The analog output and HPI cards allow for users to add multiple waveforms together. For example, a selection string of 1,2,5 would result in the waveforms configured by wavegen 1, 2 and 5 would all be added together and output on the specified channel.

sleep <milliseconds>

Sending a sleep command will cause the system to pause in between commands for the specified time. This is useful when scripting the console commands. When this command is sent the console will be locked and no other commands may be sent.

recording stop

Will stop any current recording.

sensorserial <sensor number>

Provides the serial number for a single sensor.

exec <path to script>

This command will execute the script specified by the provided system path. When this command is sent the console will be locked and no other commands may be sent.

savesensorinfo <optional path>

This command creates tab separated file (.tsv) with sensor position, sensor serial number, helmet position (if applicable), and the measured offset fields as measured when requested by this command. An example is shown:

sensorNum	serial	position	bx	by	bz
1	0U7SY7	L101	-0.05	-1.04	2.45
2	0U7ZWX	--	4.32	-0.52	-2.10
125	0U7ZZ7	--	--	--	--

A "--" indicates that there is no value for this field. In the case of position that means there is no helmet localized for this sensor. For Bx, By, and Bz a "--" indicates the sensor is not currently zeroed. The units for the displayed field are nanoTesla.

If no path is provided the file will be placed in the /tmp/ folder on the workstation. The console will show the final name of the saved file.

savesystemconfig <optional path>

This command generates a text file that displays the current system configuration information. This includes chassis serial numbers, card serial numbers, and version information. The information generated is as follows (in order from the bottom chassis to the top):

Chassis #:

serial: <chassis serial number #>

version: hedscan-x.x.x-yyyyyyyyy

Slot 1: <Card Type>

serial: <card serial number>

version: x.x.x (avail x.x.x)

Slot 2: (if empty) empty

...

Slot 16: <Card Type>

serial: <card serial number>

version: x.x.x (avail x.x.x)

If no file path is specified, the file is stored in the /tmp/ folder on the workstation. The console will show the final name of the saved file.

EXECUTING CUSTOM SCRIPTS

The console can send any number of commands via a provided script. The requirements for the script are a text-based file where each command is on its own line. [Appendix C](#) includes an example script template.



CAUTION: It is possible to lock the console in an infinite loop if a script calls itself during execution. Closing the GUI and reopening will eliminate this loop if it happens.

View Toggle

The view toggle (Figure 73) allows users to switch between HEDscan Views. The default view is “Chassis View”. If a smart helmet is installed 2D view can be selected, otherwise the toggle is disabled.

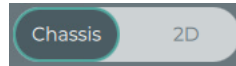


FIGURE 73 - VIEW TOGGLE

Power Options

The HEDscan GUI has a power button on the bottom footer in the lower right-hand corner (Figure 74). Selecting the button opens a context menu and allows the user to select from the following options:

- Disconnect: Returns the user to the initial system selection screen.
- Reboot: Will restart the HEDscan system, power cycling all accessory cards.
- Power Off: Device will safely shut itself down. To power back on the physical buttons must be pressed.

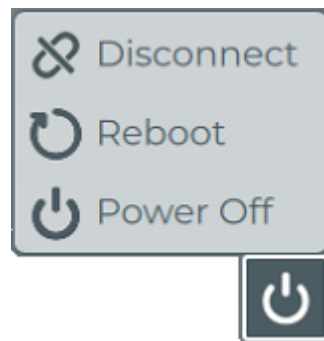


FIGURE 74 - POWER OPTIONS

HEDscan Quick Start Guide

The following section details how to restart, initialize, localize, perform a head localization, and record data.

Initial Connection

When initially connecting to HEDscan the view should appear as seen in Figure 75, where all sensors are off but selected. (Connecting to a system while sensors are on is possible but not typical).

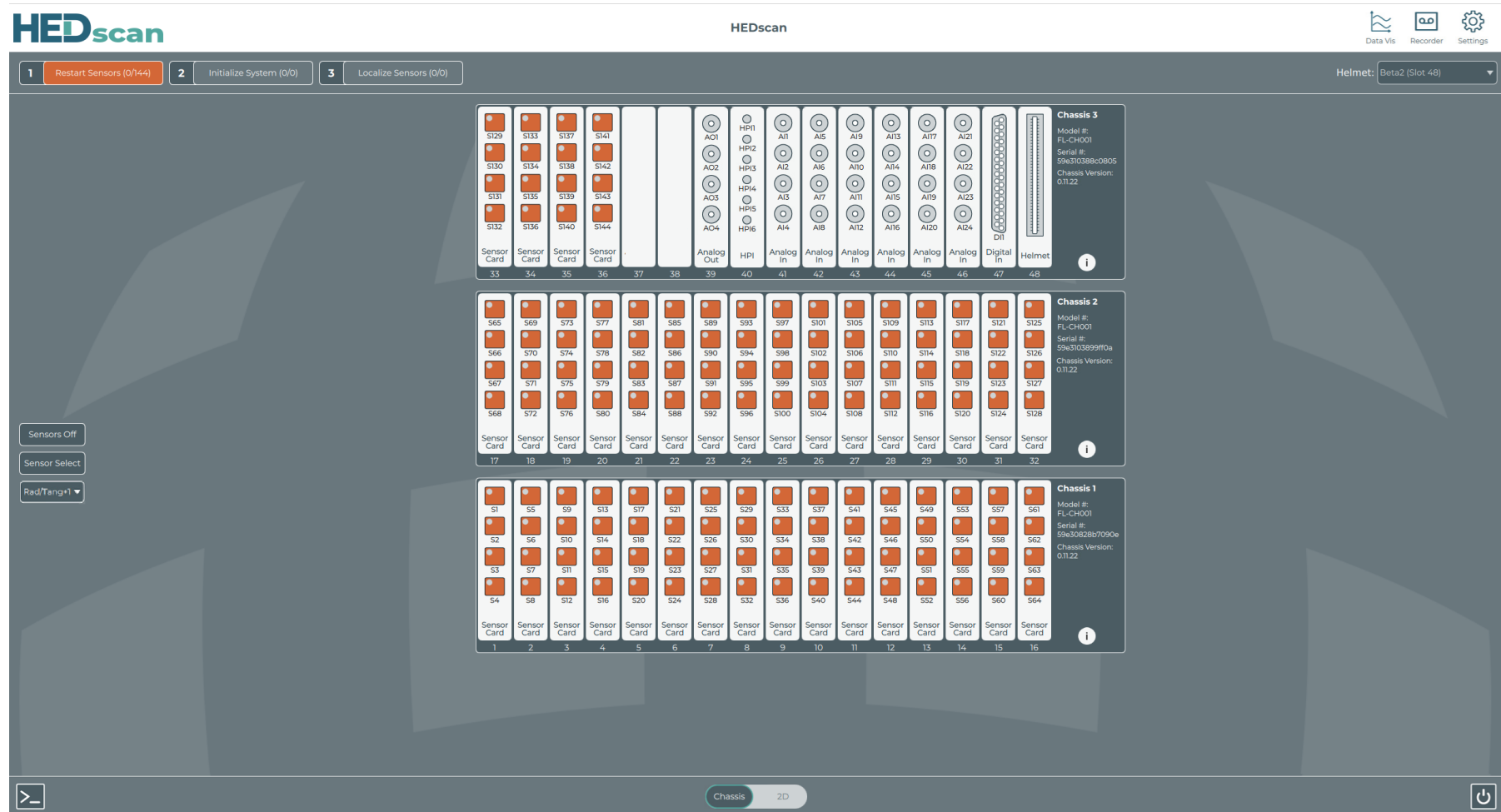


FIGURE 75 – INITIAL CONNECTION

Restart Sensors

Selecting the “Restart Sensors” button will restart all selected sensors. During the startup sequence the sensors will steadily blink green. Once complete they will be solid green with the “Initialize System” button highlighted orange (Figure 76).

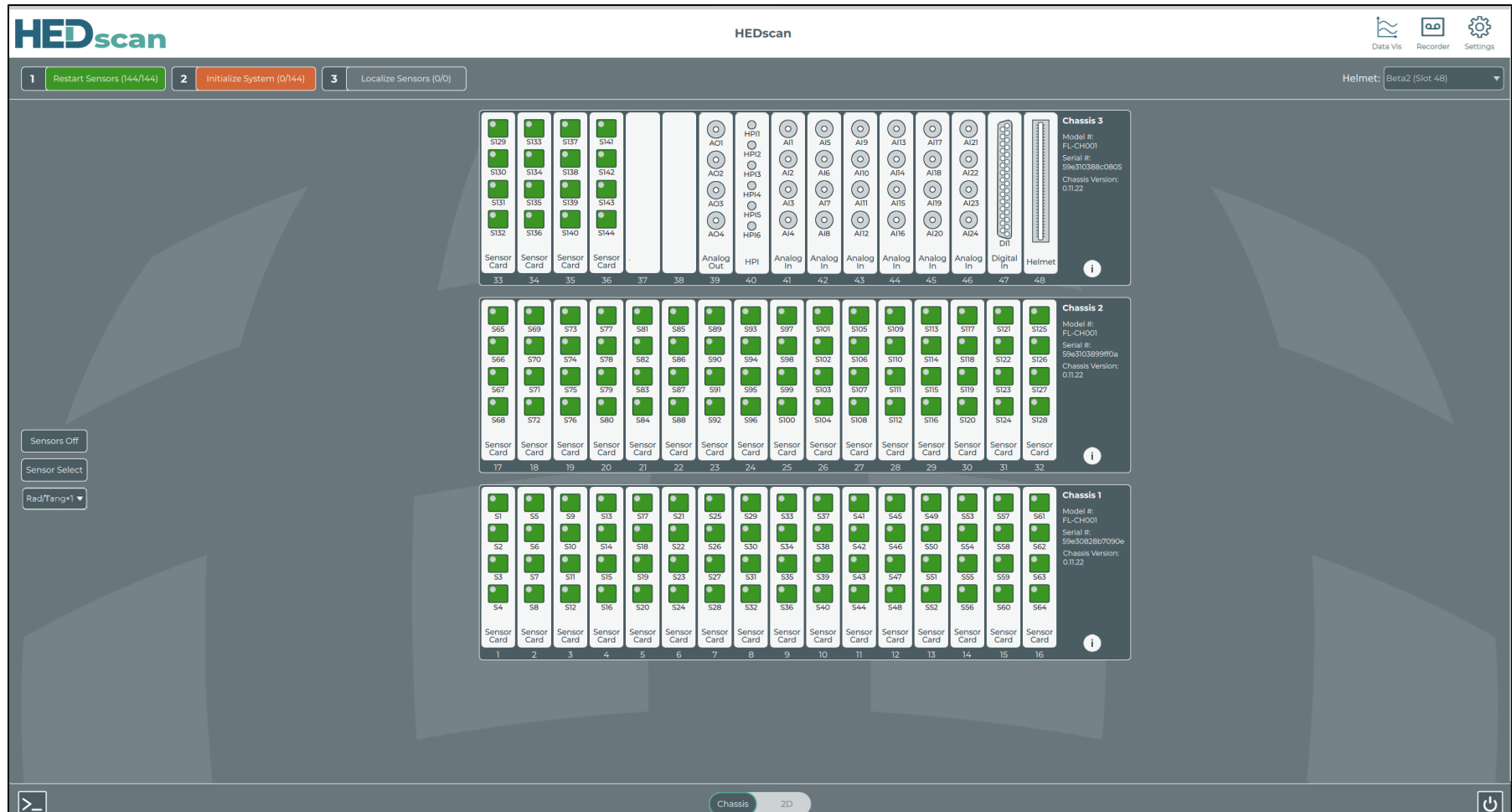


FIGURE 76 – READY TO INITIALIZE

Failed OPM

Occasionally, an OPM may fail to properly start and will be colored red (Figure 77). There will also be a notification of the failed start in the event log, located in the console command. The user can choose to proceed without handling the failed sensor, or by selecting the sensor (either left-click or via the “Sensor Select” menu) and turn it off. The “Red” restart sensors button will only return to green if the errored sensors are off.

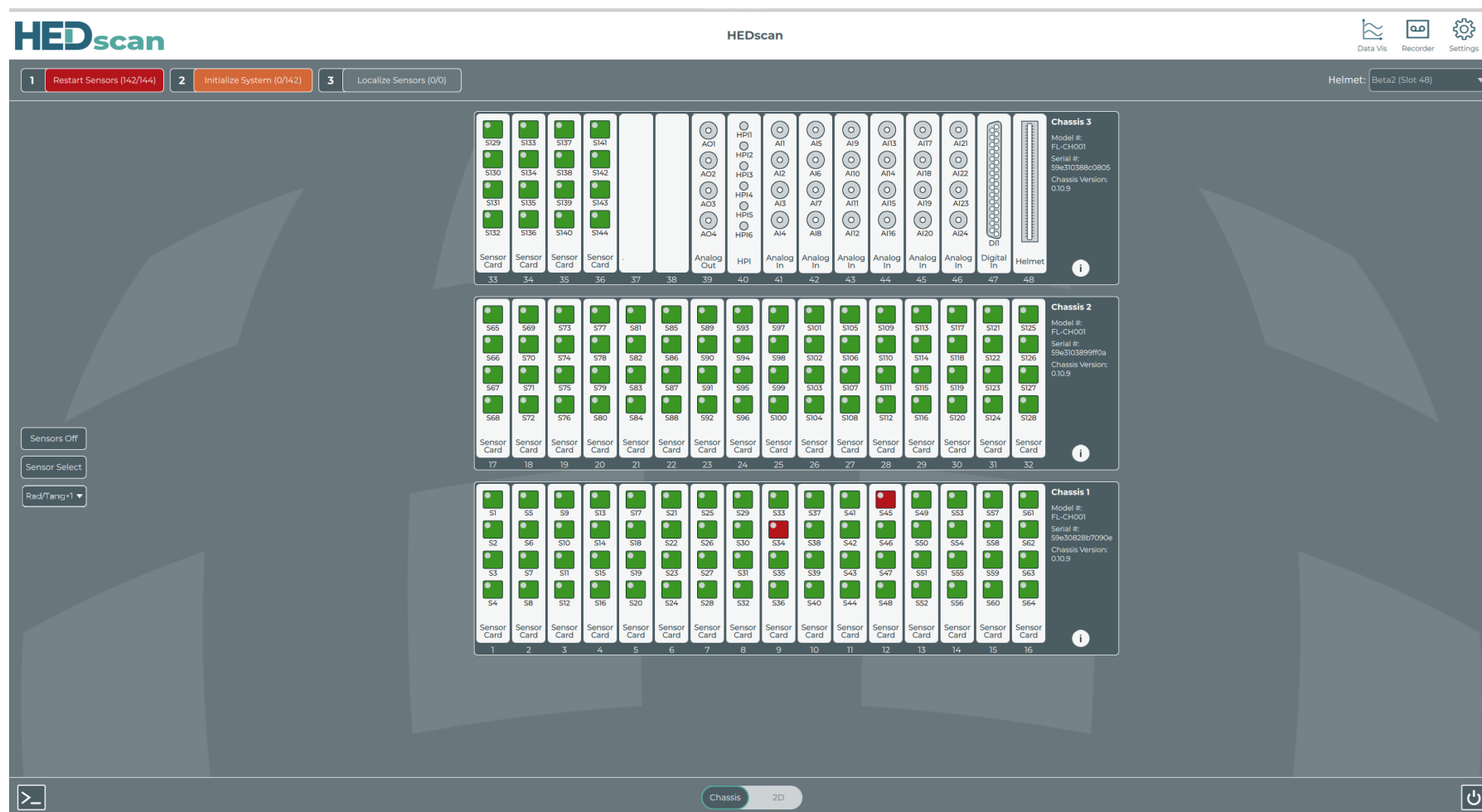


FIGURE 77 – FAILED START

Initialize System

After all OPMs are started, the user can proceed to Initialization stage by pressing the Initialize System button. If the OPMs are in a magnetically shielded area they will initialize. If they are not, they will return to the solid green state. Attempting to restart the OPMs outside a shielded area can cause the sensor to fail. In this case simply restart that OPM.

If the system has a smart helmet the user can choose to localize the OPMs installed in the helmet by selecting “Localize Sensors”. The localization process will take approximately one minute. When complete the event log in the console will display any helmet slots that showed an error or any sensor that failed to localize. Additionally, the “Localize Sensors” button will display the number localized.



FIGURE 78 – INITIALIZED SENSORS WITH LOCALIZATION

If the OPMs have failed to localize it is recommended to re-initialize the affected OPMs and attempt another localization. If this process continues FieldLine Medical recommends powering off the affected OPM and continuing with the data recording. Additionally, contact FieldLine to help diagnose the next steps for the affected OPM. At this point, the OPMs are initialized, and the system is ready to record.

Figure 79 shows a system fully localized and ready to record. If a different sensitive axis is desired (such as only the Radial Axis instead of both Radial and Tangential) perform the following steps:

- Click the drop-down menu and select “Rad”
- The HEDscan system will return the sensors to the “Restarted” state.
- Re-initialize and re-localize the sensors

After the sensors are localized, when data is recorded the *.fif file will include 12 location points for each sensor (the point corresponds specifically to the center of the sensor’s vapor cell which is centered 5mm deep from the sensors tip).

- X, Y, Z Coordinates [relative to the origin at the center of the helmet]
- X unit vectors
- Y unit vectors
- Z unit vectors

1 Restart Sensors (144/144)

2 Initialize System (144/144)

3 Localize Sensors (144/144)

Helmet: Beta2 (Slot 48)

Sensors Off

Sensor Select

Rad/Tang+ ▾

<div style="display: flex; justify-content: space-around;"> <div>S129 S130 S131 S132</div> <div>S133 S134 S135 S136</div> <div>S137 S138 S139 S140</div> <div>S141 S142 S143 S144</div> </div>								<div style="display: flex; justify-content: space-around;"> <div>AO1 AO2 AO3 AO4</div> <div>HP1 HP2 HP3 HP4 HP5 HP6</div> <div>AI1 AI2 AI3 AI4</div> <div>AI5 AI6 AI7 AI8</div> <div>AI9 AI10 AI11 AI12</div> <div>AI13 AI14 AI15 AI16</div> <div>AI17 AI18 AI19 AI20</div> <div>AI21 AI22 AI23 AI24</div> </div>				<div style="display: flex; justify-content: space-around;"> <div>D11</div> <div>Helmet</div> </div>		<div>Chassis 3</div> <div>Model #: FL-CH001</div> <div>Serial #: 59x310388c0805</div> <div>Chassis Version: 0.11.22</div>									
Sensor Card				Sensor Card				Sensor Card				Sensor Card				Sensor Card		Sensor Card					
33				34				35				36				37				38			

<div style="display: flex; justify-content: space-around;"> <div>S65 S66 S67 S68</div> <div>S69 S70 S71 S72</div> <div>S73 S74 S75 S76</div> <div>S77 S78 S79 S80</div> <div>S81 S82 S83 S84</div> <div>S85 S86 S87 S88</div> <div>S89 S90 S91 S92</div> <div>S93 S94 S95 S96</div> <div>S97 S98 S99 S100</div> </div>				<div style="display: flex; justify-content: space-around;"> <div>S101 S102 S103 S104</div> <div>S105 S106 S107 S108</div> <div>S109 S110 S111 S112</div> <div>S113 S114 S115 S116</div> <div>S117 S118 S119 S120</div> <div>S121 S122 S123 S124</div> <div>S125 S126 S127 S128</div> </div>				<div>Chassis 2</div> <div>Model #: FL-CH001</div> <div>Serial #: 59x3103899f0a</div> <div>Chassis Version: 0.11.22</div>															
Sensor Card				Sensor Card				Sensor Card				Sensor Card				Sensor Card							
17				18				19				20				21				22			

<div style="display: flex; justify-content: space-around;"> <div>S1 S2 S3 S4</div> <div>S5 S6 S7 S8</div> <div>S9 S10 S11 S12</div> <div>S13 S14 S15 S16</div> <div>S17 S18 S19 S20</div> <div>S21 S22 S23 S24</div> <div>S25 S26 S27 S28</div> <div>S29 S30 S31 S32</div> <div>S33 S34 S35 S36</div> </div>				<div style="display: flex; justify-content: space-around;"> <div>S37 S38 S39 S40</div> <div>S41 S42 S43 S44</div> <div>S45 S46 S47 S48</div> <div>S49 S50 S51 S52</div> <div>S53 S54 S55 S56</div> <div>S57 S58 S59 S60</div> <div>S61 S62 S63 S64</div> </div>				<div>Chassis 1</div> <div>Model #: FL-CH001</div> <div>Serial #: 59x30828c7090e</div> <div>Chassis Version: 0.11.22</div>															
Sensor Card				Sensor Card				Sensor Card				Sensor Card				Sensor Card							
1				2				3				4				5				6			

Chassis 2D

Power

FIGURE 79 - FULLY LOCALIZED

Head Localization

If the user has an HPI card installed in the system head localization is required to record data unless the “Bypass Head Localization” option is selected. To localize the head, open the HEDscan Recorder and after filling in the required fields (see HEDscan Recorder section) the “Localize Head” button will turn orange. Select the button and the system will localize the head. After completing, a new window (Figure 80) will open with a 3D representation of the HPI and smart helmet. If the HPIs are determined to be in accurate positions the system will allow a recording to take place and the “Localize Head” button will turn green and the “Record” button will turn orange and become selectable. HPI positions will be included in the *.fif recording with their positions in the helmet coordinate system as well as the raw head localization scan from which the positions were determined.

If the system detects the following error conditions:

- Asymmetry between the LPA-NAS and RPA-NAS
- Inverted LPA/RPA
- GOF below 0.98
- Missing HPI coil
- Distance between LPA and RPA greater than 22 cm [size of helmet] or less than 10 cm

It will display the error and not allow the recording to take place. If any of these errors are encountered enter the MSR and adjust the HPI positions. Alternatively, the “Bypass Head Localization” can be selected.

NOTE: The HPI configuration in the settings must be completed to localize the head, i.e. indicating to the system where the Nasion, LPA, and RPA are. Automatic head localization will fail without these 3 points.

NOTE: If desired, HPI can still be run via the manual scripts as described in Appendix D. If this process is preferred check “Bypass Head Localization” to proceed as normal. Similarly, to perform an empty room recording without HPI, check “Bypass Head Localization”.

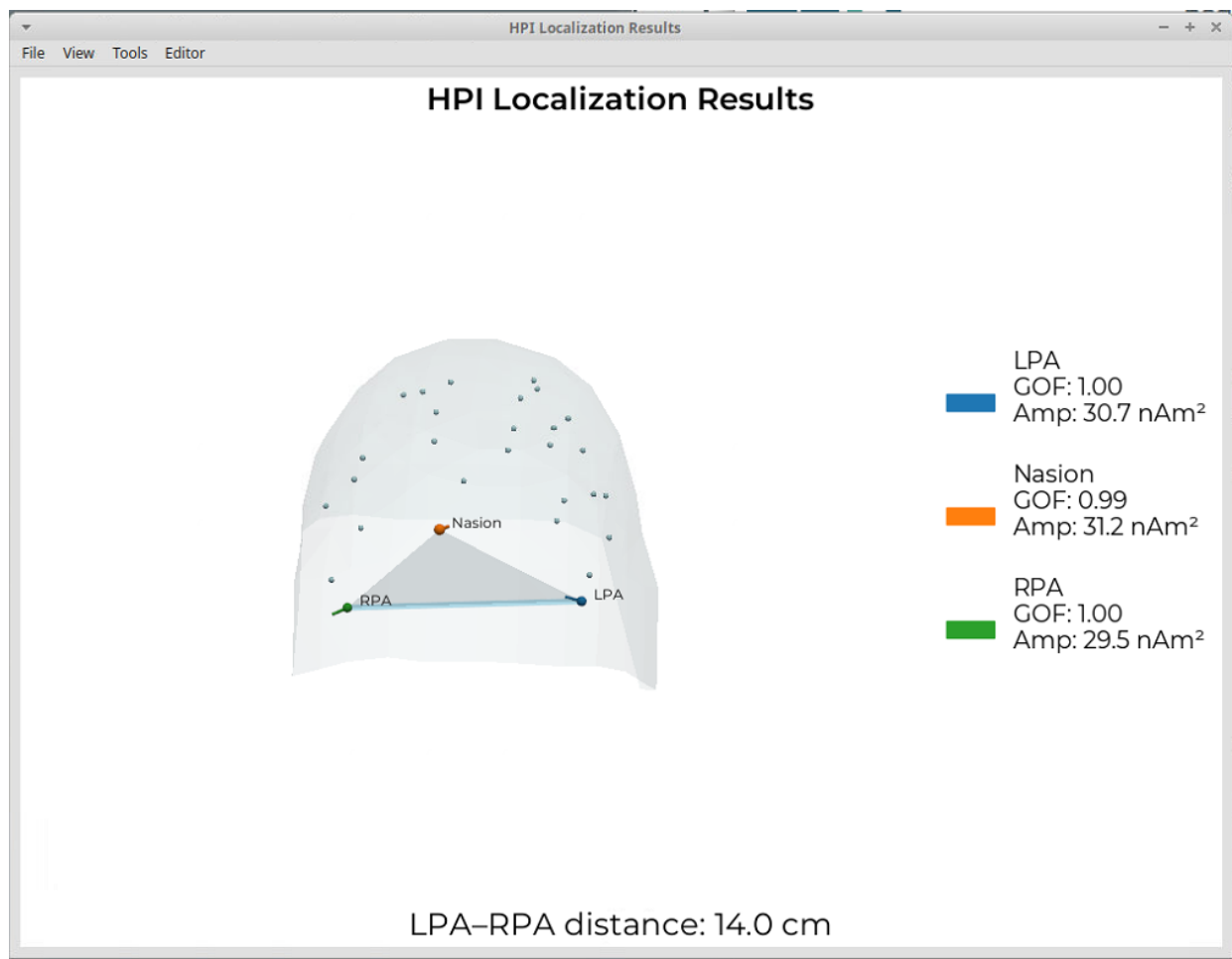


FIGURE 80 - LOCALIZED HEAD

Accessory I/O Configuration

The analog input, analog output, HPI, and digital cards are enabled by double clicking on their port icon as indicated above. To configure the waveforms on the analog output or HPI card see the console command section. An enabled accessory card will be highlighted blue as seen in Figure 81.

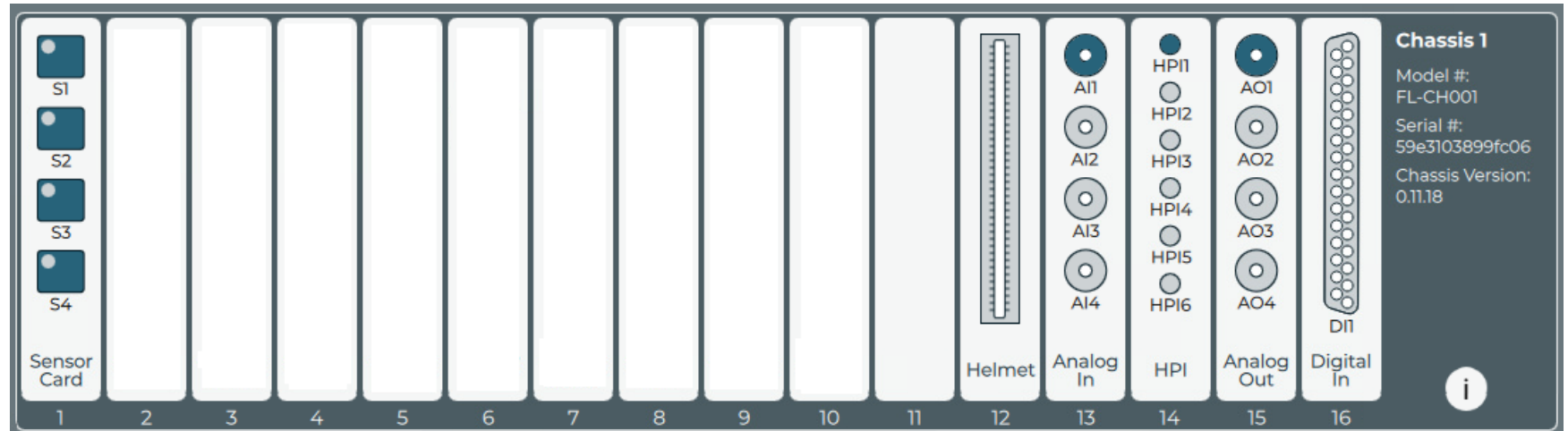


FIGURE 81 - ACCESSORY VIEW

HEDscan Updates

Updates to HEDscan are performed in a potential 3 step process. The first step involves updates to the HEDscan Ubuntu package. FieldLine Medical will send out a notification via email when an update is available. Additionally, if the Linux update manager has network access, it will periodically check if an update is available and notify the user. This update can be performed in one of two ways.

1. Open a terminal and issue the commands:

```
sudo apt update  
sudo apt upgrade
```

2. Alternatively via the Ubuntu Software Updater pictured in Figure 82.

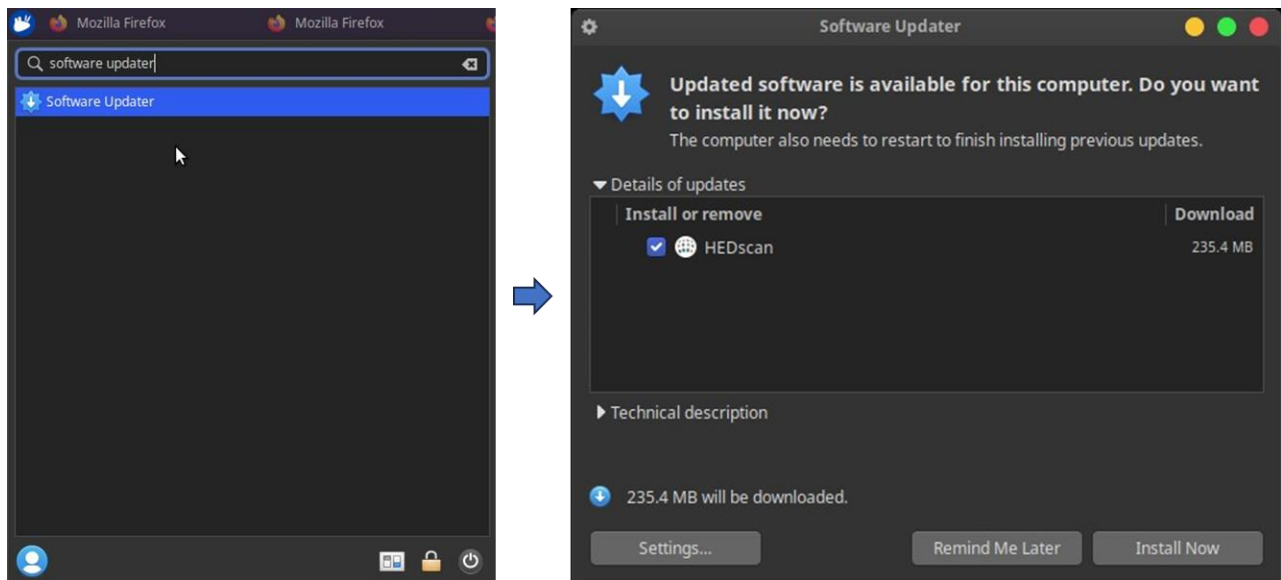


FIGURE 82 – UBUNTU SOFTWARE UPDATER

After updating the Ubuntu package, upon opening the HEDscan GUI and connecting to the system, the user will be prompted to proceed with an update as pictured below in Figure 83. Upon accepting the prompt, the Update Settings dialog (Figure 56Error! Reference source not found.) will be opened (another way to get to the settings dialog is to select the gear icon in the upper right corner of the GUI).

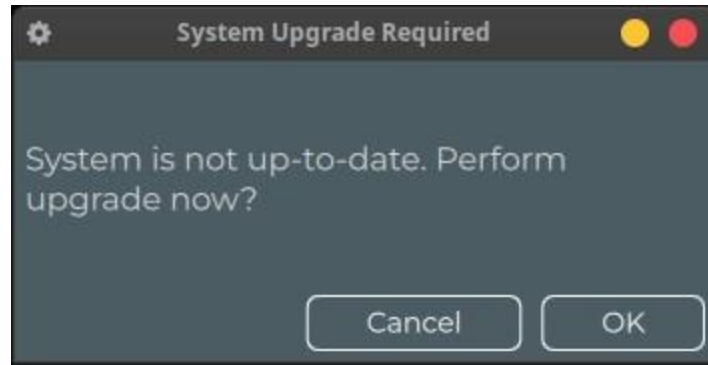


FIGURE 83 – UPDATE DIALOG

This process will take approximately 5 minutes and will include a system reboot. Upon completion any accessory card that has out of date firmware will show the following yellow box (Figure 84).

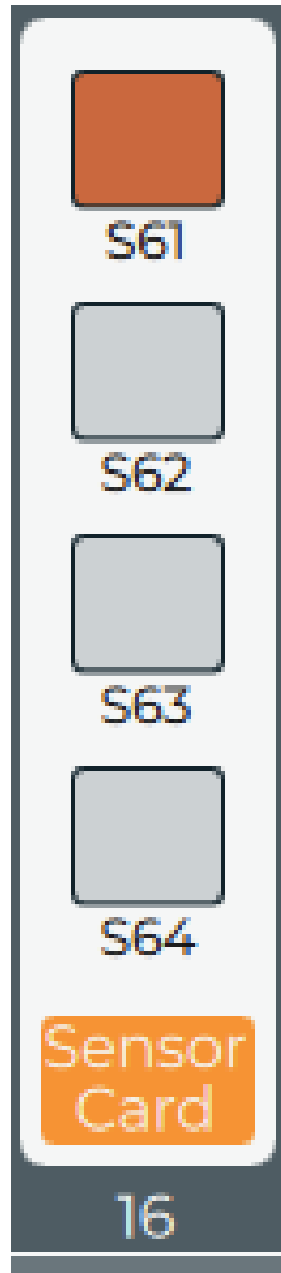


FIGURE 84 – OUT OF DATE FIRMWARE

Click on the “Gear” icon to go to HEDscan settings and select the firmware update button. Each out-of-date card takes approximately 5 minutes to update. If all 16 cards are out of date it will take approximately 70 minutes to complete. The system will reboot when it is finished applying these updates.

HEDscan API

HEDscan allows the user to interact via an API. To install the API run the following command:

```
sudo apt install python3-hedscan
```

Once the API is installed an example script is provided to get started. It can be found at the following path:

```
/usr/share/hedscan/example/hedscan-api-example.py
```

Additionally, there is an even more pared down version of the example API script called:

```
/usr/share/hedscan/example/barebones-example.py
```

This script makes for a good starting point for any API based script.

Safety Notices

1. Read, follow, and keep these instructions.
2. Heed all warnings.
3. Only use attachments/accessories specified or approved by FieldLine Medical.



WARNING: Failure to provide proper ventilation may cause fire hazard. Keep at least 20 mm of clearance next to the ventilation holes for adequate airflow.



WARNING: To reduce the risk of fire or electric shock, do not expose this product to rain or moisture.



WARNING: Do not use this product in locations that can be submerged by water. OPMs are not certified to operate in an aquatic environment.



WARNING: Avoid using this product during an electrical storm. There may be a remote risk of electric shock from lightning.

Troubleshooting

OPM indicator color is red:

- If red on first connection contact FieldLine Medical Support (support@fieldlineinc.com).
- If red after restarting it is recommended to wait approximately 30 seconds, individually select that OPM and restart. If it continues to fail, contact FieldLine Medical Support.

Sensor Card Box is highlighted red:

- Contact FieldLine Medical Support

OPM Fails to Initialize (fails back to solid green):

- Individually select the OPM (left-click + ctrl) and try reinitializing.
- If it continues to fail attempt a restart of the individual OPM
- If failures continue, power all sensors off and try to reseal the cable at the chassis or alternatively swap sensor with a neighboring sensor.
- Further failures contact FieldLine Medical Support and provide a diagnostic file.

Appendices

Appendix A – Revision History

Rev 2023.11.06 – Nov 2023: <ul style="list-style-type: none">- Initial Document Release
Rev 2023.11.14 – Nov 2023 : <ul style="list-style-type: none">- Added Disclaimer
Rev 2024.02.29 – Feb 2024: <ul style="list-style-type: none">- Adjusted data convention in the versioning to YYYY.MM.DD- Rearranged Hardware Overview- Added Figure showing OPM orientation and dimensions- Expanded on Beta 2 Helmet Section- Updated HPI card section- Updated Digital Input card section to include pin connection table- Added sections describing the Compute Module and Power Thermal Controller (PTC)- Renamed references to the Carrier Card to Compute Module- Added section on Multiple Chassis Configuration- Updated settings dialog- Added new figure showing failed localization- Update console commands section- Added Appendix B, C, and D
Rev 2024.03.29 – Mar 2024: <ul style="list-style-type: none">- Updated console commands section to add information about savesensorinfo and savesystemconfig commands. (pg. 44-pg. 47)- Removed settings dialog from HEDscan Updates section to improve consistency- Added additional troubleshooting steps (pg. 71)- Added Appendix E to highlight network configuration information. (pg. 76)
Rev 2024.05.17 – May 2024: <ul style="list-style-type: none">- Updated settings dialog to include diagnostics collection.- Added Filters section under Data Visualizer section.- Updated figures to reflect the addition of the filter button

Rev 2024.07.12 – July 2024:

- Updated settings dialog to include “Install Parameters”
- Updated HEDscan Initialization section to reflect new sensor selection options

Rev 2024.10.15 – Oct 2024:

- Added HEDscan API section
- Updated sensor selection to match updates
- Updated Data Visualizer section to include updated images
- Added Channel Select and Axis Setting to Data Visualizer section
- Updated images throughout to reflect change from “Recording” → “Recorder”
- Updated HEDscan Recorder section to signify a “.” Is now allowed in filenames

Rev 2024.11.18 – Nov 2024:

- Updated truefield section to better explain the purpose
- Updated Data Vis section to better explain what data is represented on the time series.
- Updated appendices B and D to incorporate the new HPI analysis tools

Rev 2025.05.14 – May 2025:

- Updated settings dialog
- Updated GUI look and feel (buttons show as pressed, adjusted record icon, etc...)
- Added tri-axial support
- Added pop-up warnings
- Added info about fif location data to the localization section
- Moved HEDscan API section

Rev 2025.11.12 – Nov 2025:

- Copyright
- Minor verbiage updates throughout
- Completely restructured "Using HEDscan" system to clarify details of using the system and many new features introduced in 0.11
- Updated images throughout to reflect update to 0.11
- Adjusted Appendix D to reflect Head Localization introduction

Appendix B – Update FIF Script

FieldLine Medical has created “update_fif.py” to modify previously recorded fif files to either correct them or add additional information. The script supports the following modifications:

1. Corrects magnetic field polarity inversion (issue was present prior to the 0.5 software release)
2. Re-analyzes a helmetscan and updates sensor locations accordingly (address an issue present prior to 0.5 software release)
3. Adds HPI scan location results, and optionally head digitization points

The following subsections detail how to perform the separate processes listed above. However, it is also possible to re-perform a helmetscan analysis and update HPI positions in one step. Simply include all the relevant files as described by both sets of instructions prior to running the script.

Helmetscan Analysis

To re-analyze a helmetscan the following steps must be taken:

1. Create a new folder and store recordings associated with a specific helmet scan.
2. Copy the associated helmet scan.
 - a. Helmet scans can be located at: `~/local/share/HEDscan/helmetscans/*.fif`
(Note: Hidden Folders must be set as visible).
3. Copy all *.fif files to be updated that were taken with the above helmet scan.
4. Right click inside this folder to open a terminal at this location. Run:

```
update_fif.py
```

The script will update the locations inside each *.fif file and store them in a new output directory.

The script will not run on files that have already been updated. It will also not delete the original data.

To determine files associated with the helmetscan look for the timestamps immediately following the one on the helmetscan file.

Contact FieldLine Medical support for any assistance performing this process.

HPI Location Incorporation

To add HPI coil locations to one or more fif recordings, the following steps must be taken:

1. Create a new folder and store recordings associated with the specific HPI scan whose locations are to be added.
2. Ensure the appropriate *_hpi_results.csv is in the new directory.
 - a. Refer to Appendix D for HPI analysis
3. Right click inside this folder to open a terminal at this location. Run:

```
update_fif.py
```

The script will update the locations inside each *.fif file and store them in a new output directory.

If desired, extra digitization points can be added to the fif file by including the -e flag to update_fif.py. These points represent the surface of the patient's head and are based off of the sensor locations (assuming the sensors are making contact with the patient's head).

Contact FieldLine Medical support for any assistance performing this process.

Appendix C – Example Console Command Script

Below an example template is provided for scripting the console command. This example will:

1. Enable a 33.5 Hz sine wave with 5V amplitude on an Analog Output Card
2. Enable the streamctl for both Analog Output and Input Cards
3. Sleep the console for 1 second

In this example it is presumed that a BNC cable would be connecting the two cards together.

```
wavegenctl 1 -s sin -f 33.5 -a 5.0  
streamctl enable aout <ANALOG OUT PORT NUM>  
streamctl enable ain <ANALOG IN PORT NUM>  
aoutctl <ANALOG OUT PORT NUM> wavegen 1  
sleep 1000
```

To try this file, copy the above lines, identify the specific analog input and output ports, and then save in a text-based file. If the file is called example.script it can be ran by sending the following command:

```
exec <path to script>/example.script
```

[Appendix D – HPI](#)

Note: As of update 0.11 HEDscan has incorporated a comprehensive “Localize Head” capability as described in section “Head Localization”. The following is the prior method to applying the HPI coils.

Note: Changes to this workflow can be made to fit individual requirements.

Create HPI Operation Scripts

To operate the HPI coils more efficiently scripts can be created and run in the console command window (as explained in Appendix E). Creation of the following three scripts is required for this example workflow.

setuphpi.script: Enables the HPI ports on a specified card. (Repeat the below two lines for each port desired). An example script enabling 5 ports on an HPI card located in slot 12 of a single chassis is shown below (the port numbers need to match the system operated upon):

```
streamctl enable hpiin 1
streamctl enable hpiout 1
streamctl enable hpiin 2
streamctl enable hpiout 2
streamctl enable hpiin 3
streamctl enable hpiout 3
streamctl enable hpiin 4
streamctl enable hpiout 4
streamctl enable hpiin 5
streamctl enable hpiout 5
```

disablehpi.script: Disables and removes HPI ports when finished

```
streamctl disable hpiin 1
streamctl disable hpiout 1
streamctl disable hpiin 2
streamctl disable hpiout 2
streamctl disable hpiin 3
streamctl disable hpiout 3
streamctl disable hpiin 4
streamctl disable hpiout 4
streamctl disable hpiin 5
streamctl disable hpiout 5
```

performhpi.script: Creates the wavegens to operate the HPI coils and then applies them sequentially to each coil. The example below continues with the above assumptions. (Changes to the ports are necessary for HPI cards in different locations). Note that the frequency chosen for this example is 23 Hz. Currently we suggest using frequencies below 40 Hz as the HPI localization results will be more likely to be correct. However, it is recommended that the spectrum in your specific environment is accounted for when choosing an HPI frequency.

```
wavegenctl 1 -s sin -f 23 -a 5 -c
wavegenctl 2 -s sin -f 23 -a 2 -c
wavegenreset
sleep 100
hpictl 1 wavegen 1
sleep 3000
hpictl 1 wavegen 2
sleep 3000
hpictl 1 wavegen 0
sleep 100
hpictl 2 wavegen 1
sleep 3000
hpictl 2 wavegen 2
sleep 3000
hpictl 2 wavegen 0
sleep 100
hpictl 3 wavegen 1
sleep 3000
hpictl 3 wavegen 2
sleep 3000
hpictl 3 wavegen 0
```

```
sleep 100
hpictl 4 wavegen 1
sleep 3000
hpictl 4 wavegen 2
sleep 3000
hpictl 4 wavegen 0
sleep 100
hpictl 5 wavegen 1
sleep 3000
hpictl 5 wavegen 2
sleep 3000
hpictl 5 wavegen 0
sleep 100
hpictl 6 wavegen 1
sleep 3000
hpictl 6 wavegen 2
sleep 3000
hpictl 6 wavegen 0
sleep 1000
recording stop
exec <path to script>/disablehpi.script
```

Perform HPI Scan

Once the HPI scripts have been generated, assuming the HPI card has not changed locations, they should not have to be created again. Attach HPI coils to the subject prior to placing them in the shield area. HPI coils must be attached to the Nasion, LPA and RPA locations. Additional coils are not used in the current calculations; however they can provide additional dimensional information to check against an existing MRI.

The order in which the coils are plugged into the HPI driver card ports is expected to be as follows, from top to bottom: Nasion, LPA, RPA, Inion, Cz. For the example system described above with the HPI card in slot 12 of the first chassis, this results in the following port order (assuming the only HPI card in the system): Nasion in 1, LPA in 2, RPA in 3, Inion in 4, Cz in 5.

If an HPI recording was collected with the coils attached in a different order it may be specified with the -i argument to update_fif.py (see the script --help output for more information).

Once the OPMs have been initialized and localized an HPI scan can take place.

To perform the HPI perform the following:

1. In the console run the command:

```
exec <path to script>/setuphpi.script
```

2. Start an untimed recording.
3. In the console run the command:

```
exec <path to script>/performhpi.script
```

4. Wait for script to finish. The console will indicate when the recording has been stopped automatically. While the script is running observe the live FFT viewer to verify the coils are energizing and being detected by the OPMs.
5. Open a terminal window in the Linux workstation.
6. Type the following commands:

```
$ hedscan_hpiscan.py <path to file>/<hpi_scan>_raw.fif
```

7. If desired, the command can be run using the -p option to generate a plot.
8. Verify that the outputs of the HPI locations appear correct. If there are errors reported (shown below) try to record again or adjust HPI amplitudes.
9. Record data as normal.
10. Once finished collecting data run update_fif.py. See Appendix B for instructions on using update_fif.

HPI Scan Analysis Script

The script `hedscan_hpiscan.py` is included with each HEDscan release. This script localizes HPI coils and can provide some basic error checking for quick validation. To run the script open a Linux terminal and type:

```
hedscan_hpiscan.py <path to file>/<hpi_scan>_raw.fif
```

Running the script with no arguments will produce output that looks similar to the following:

```
Segmenting HPI scan...
Discarding 6 noisy channels: L105_bz-s81 L312_bz-s79 R205_bz-s103 R301_bz-s110 R310_bz-s105 R410_bz-s47
Computing segment amplitudes (bounds [2e-13, 1e-08])...
Localizing Channel 1 Segment 0...
Localizing Channel 2 Segment 0...
Localizing Channel 3 Segment 0...
Localizing Channel 4 Segment 0...
Localizing Channel 5 Segment 0...
Results saved to 20241009_155626_sub-helmet18_file-hpi_hpi_results.csv
```

HPI Self-Test Results:

Chan	Identity	Self-Test
1	NASION	PASS
2	LPA	PASS
3	RPA	PASS
4	INION	PASS
5	CZ	PASS

HPI Scan Segment Summary:

Chan	Identity	Seg	Len (s)	Freq (Hz)	Amp (mA)	MEG	Chs	Amp Range (T)
1	NASION	0	9.9	33.001	0.201	127		5.11e-13 -- 3.06e-10
2	LPA	0	10.0	33.000	0.201	127		-6.91e-13 -- 2.83e-09
3	RPA	0	9.9	33.000	0.201	128		-7.67e-13 -- 2.27e-09
4	INION	0	9.9	33.000	0.201	127		-1e-12 -- 1.56e-09
5	CZ	0	9.9	33.000	0.201	128		-4.55e-13 -- 8.37e-10

HPI Localization Results:

Chan	Identity	Seg	GOF	Location (cm)	Moment Norm
1	NASION	0	0.999	[-0.144 8.117 0.379]	3.35687e-08
2	LPA	0	0.999	[-7.564 -0.515 1.696]	3.44071e-08
3	RPA	0	0.998	[7.925 0.703 -2.962]	3.24722e-08
4	INION	0	1.000	[0.458 -7.653 -1.787]	3.34739e-08

5 CZ 0 0.998 [0.481 -1.057 7.076] 3.21942e-08

Checking HPI scan results:

NASION has 1 valid location results

LPA has 1 valid location results

RPA has 1 valid location results

Cardinal point checks:

NASION PASS

LPA PASS

RPA PASS

LPA-RPA 16.2 cm

NASION-LPA 11.5 cm

NASION-RPA 11.5 cm

All cardinals present and passing

Sometimes there will be errors detected by the script. The results might look as follows:

Segmenting HPI scan...

Discarding 6 noisy channels: L105_bz-s81 L312_bz-s79 R205_bz-s103 R301_bz-s110 R310_bz-s105 R410_bz-s47

Computing segment amplitudes (bounds [2e-13, 1e-08])...

Localizing Channel 1 Segment 0...

Localizing Channel 2 Segment 0...

Localizing Channel 3 Segment 0...

Localizing Channel 4 Segment 0...

Localizing Channel 5 Segment 0...

Results saved to 20241009_153305_sub-helmet18_file-hpi_hpi_results.csv

HPI Self-Test Results:

Chan	Identity	Self-Test
1	NASION	PASS
2	LPA	PASS
3	RPA	PASS
4	INION	PASS
5	CZ	PASS

HPI Scan Segment Summary:

Chan	Identity	Seg	Len(s)	Freq(Hz)	Amp(mA)	MEG	Chs	Amp	Range (T)
1	NASION	0	9.8	33.000	0.201	126	8.56e-13	--	-3.66e-11
2	LPA	0	9.9	33.001	0.201	126	-7.36e-13	--	4.39e-10
3	RPA	0	9.9	33.000	0.201	126	9.67e-13	--	2.03e-10
4	INION	0	9.9	33.001	0.201	126	8.65e-13	--	-4.95e-09
5	CZ	0	9.9	33.000	0.201	126	-3.49e-13	--	-5.93e-11

HPI Localization Results:

Chan	Identity	Seg	GOF	Location (cm)	Moment Norm
1	NASION	0	0.979	[-4.258 12.94 -4.081]	9.71637e-08
2	LPA	0	0.998	[-7.565 -0.991 -1.524]	3.37182e-08
3	RPA	0	0.997	[7.456 1.258 -6.114]	3.58198e-08
4	INION	0	1.000	[1.018 -7.774 -4.925]	3.14052e-08
5	CZ	0	0.819	[0.589 -1.048 3.937]	3.40582e-08

Checking HPI scan results:

NASION segment 0 gof 0.978 < 0.98

NASION has no valid location results

LPA has 1 valid location results

RPA has 1 valid location results

Cardinal point checks:

NASION **FAIL**

LPA **PASS**

RPA **PASS**

Not all checks passed, consider performing another HPI scan

Finally, if the -p argument is appended to the command (as seen below) a 3D plot will be displayed to allow for easy validation of an HPI scan.

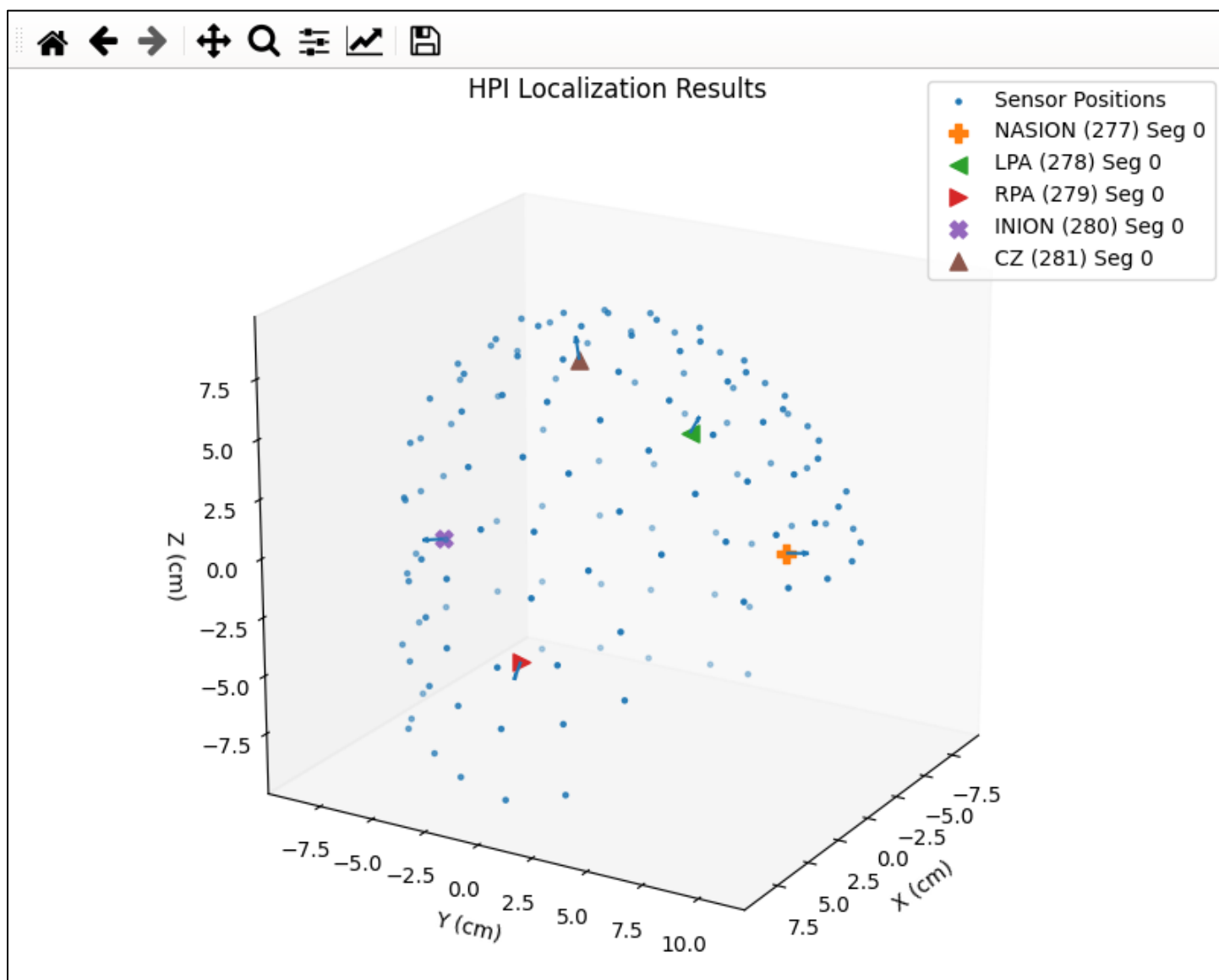


FIGURE 85 – HPI LOCALIZATION PLOT

Appendix E – Network Configuration

- HEDscan utilizes an IPv6 multicast discovery on UDP outbound port 7711. The system responds on UDP incoming port 7712 (prior to 0.6 the port was ephemeral but is now fixed).
- Connection to the HEDscan system is established using outbound TCP ports 7755/7766.
- The outbound TCP port 22 is required for certain operations.