B-Alert®

User Manual

Advanced Brain Monitoring
advancedbrainmonitoring.com

Contents

Chapter 1: Introduction

1.1 B-Alert Overview

B-Alert Software (BAS) acquires, presents, and stores physiological signals from the following ABM X-Series devices: X24-qEEG, X24-stERP, X10-Standard, X4-BAlert and X4-Sleep Profiler. BVS also has functionality for retransmitting data, computing and displaying real-time cognitive metrics, administering baseline cognitive assessments, and replaying data offline. The software has a modular architecture that allows the users to interact either using the Graphical User Interface (GUI) provided with the installation, or programmatically (refer to *B-Alert Software Programmer's Manual*) via the included Software Development Kit (SDK). The data outputs are saved in the universally compatible EDF+ format.

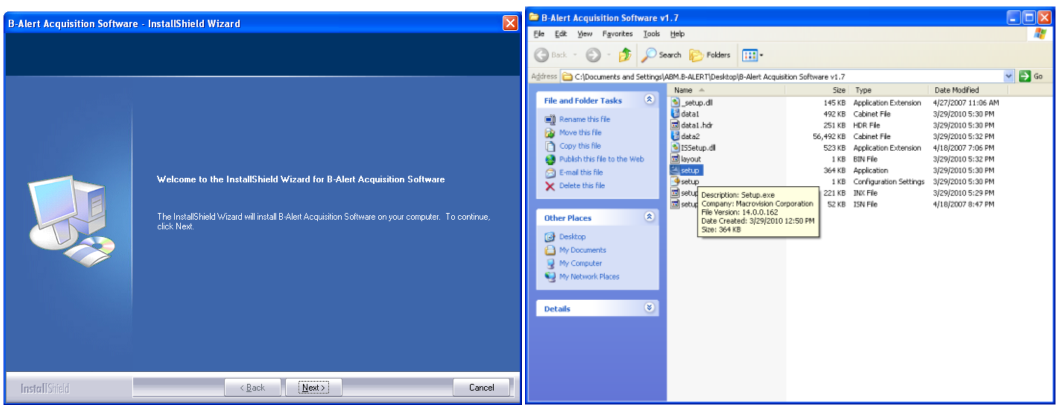
1.2 Minimum System Requirements

- Personal computer (PC) with minimum Pentium™ 2.4 GHz processor
- Minimum of 2 GB of installed RAM memory and 4 MB virtual memory
- Windows XP or Windows 7 operating system
- .NET framework version 3.5 installed
- Minimum of 50 MB hard disk space per 5-hour session
- One CD-ROM drive
- VGA or higher resolution video adapter
- One available USB port (two for validation)
- Monitor size between 15” and 21” required for Baseline acquisition

Chapter 2: Software Installation

1. Insert the B-Alert Acquisition Software Installation Disc into the CD-ROM drive, or download the installation folder from the provided link/FTP.

2. Open the CD-ROM drive or unarchive the zip folder and double click on the *setup.exe* file. The *B-Alert Acquisition Software – InstallShield Wizard* will appear. Follow the on-screen instructions to install the software.



3. A Shortcut to the B-Alert Software will automatically be installed to your desktop.

4. ABM recommends retaining the default installation folder, C:\ABM\B-Alert.

Chapter 3: Software Registration

Once B-Alert is installed, the first time a user opens the software a pop-up window will appear with a Key-A. Obtain a valid license Key-B as follows:

1. Copy the Key-A displayed in the registration box.

2. Email the Key-A to licensing@b-alert.com with your name and company affiliation.

3. In the license pop-up window, enter the Key-B obtained from ABM licensing support.

Note1: Registration will only need to be completed once. All future software upgrades will use the same registration key.

Note2: The registration key is linked to the PC hardware, and is therefore computer-specific. Each software purchase allows for up to 2 unique licenses. Please contact ABM licensing support with any issues.

Chapter 4: Compliance

4.1 Software License Agreement

The purchase of a B-Alert sensor headset entitles the Purchaser to a nonexclusive, single-use software license ("Software") from Advanced Brain Monitoring, Inc. subject to the following conditions:

The Purchaser may install the Software on only one computer, make one copy in machine readable form solely for backup purposes, provided that you reproduce all proprietary notices on the copy; and physically transfer the Software from one computer to another provided that the Software is used only on one computer at a time. The Purchaser may not copy, distribute, rent, lease, sub-license, transfer or use the Software except as allowed herein. The Purchaser may not alter, modify, decompile, translate, disassemble the Program; or use it to create a derivative work. Purchaser's right to use this Software automatically terminates upon failure to comply with any provision of this License or upon your destruction of all copies of the Program and documentation. Purchasers in good standing will be offered future improvements or upgrades to the Software. If Purchaser purchases an upgrade version of the software, it constitutes a single product with the Software that the purchaser upgraded. This License is deemed made, accepted and delivered in the State of California and shall be construed, interpreted and governing by the laws of the State of California, without regard or effect given to its or any other jurisdiction's conflicts of law jurisprudence.

Chapter 5: B-Alert Graphical User Interface (GUI)

5.1 ABM data acquisition devices and peripherals

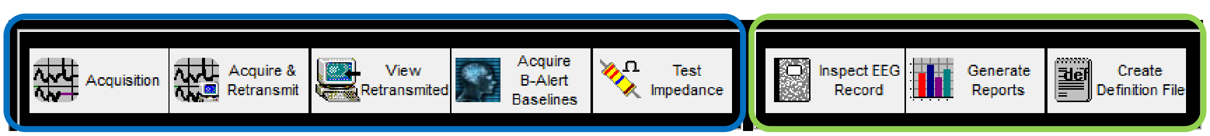
B-Alert Headset
-X4 -X10 -X24

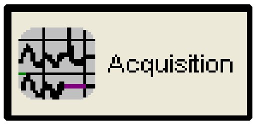
B-Alert USB Receiver
B-Alert Dongle or ESU

5.2 Overview of Online Data Acquisition Actions

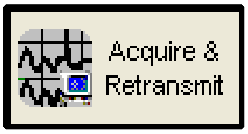
The B-Alert Acquisition Software has 5 Online Action icons located in the upper left corner of the screen. The Online Action icons are functions related to live physiological recording: signal quality checks, data acquisition, and monitoring of data acquisition. The Offline Action icons are functions related to data handling for previously recorded signals. See **Chapter 9** for detail on Offline Actions.

Online Actions **Offline Actions**

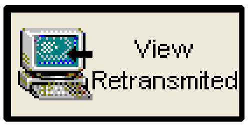




The *Acquisition* function allows users to start/stop data acquisition with the B-Alert Headset. The communication port is automatically detected, and the Headset Configuration is automatically informed.

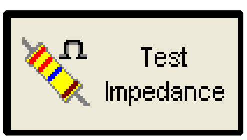


The *Acquire & Retransmit* function allows users to begin data acquisition with the B-Alert Headset on a primary computer and automatically stream live data across a TCP/IP connection. The transmitted signals can then be viewed on a second computer using the View Retransmitted function. Both computers must be connected on a local area network. **Note:** when using this function, data is only stored on the primary computer (not on the secondary machine).



The *View Retransmitted* function allows users to view live signals (raw EEG signals and real time metrics). This function is intended for use on a monitoring unit (secondary computer) when the primary acquisition computer is set to retransmit using the Acquire & Retransmit function. This function does NOT store any data on the secondary computer viewing data. Data will only be stored on the computer running the 'Acquire & Retransmit' function.

The *Acquire B-Alert Baselines* function allows the experimenter to run the three B-Alert Baseline tasks required for definition file (.def file) creation: 3-Choice Vigilance task, Eyes Open, and Eyes Closed. An individualized definition file is **required** to generate ABM's EEG classification outputs (B-Alert and Workload) for a participant.

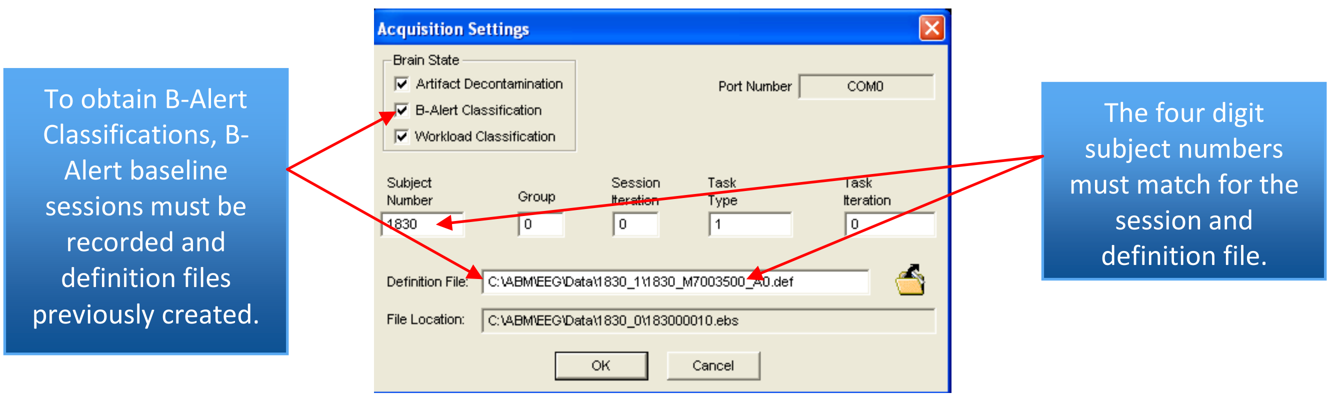


The *Test Impedance* function allows the user to test the impedance levels at each electrode site. Low impedance (<40 kOhm) is recommend to ensure good quality of data. The lower the impedance values, the better the conductivity between the scalp and electrodes and thus the better the quality of the signal.

5.3 Acquisition

Before starting an Acquisition, plug the B-alert USB Receiver into the PC and turn the headset to ON. Wait for the solid green LED pattern on the B-Alert headset (and, if you are using an ESU, the solid light on the ESU) to confirm that the B-Alert USB Receiver and Headset have established a connection. Click on the "Aquistion" button to automatically find the communication port and open the Acquisition Settings dialog box.

A 9-digit number will be assigned to each session. As shown in the Acquisition Settings dialog box below, the first four digits are required for the subject number, two digits are provided for the task type, and the other three categories only allow for a single digit to be entered. If any fields or digits are left blank, zeros will be automatically inserted in front of the entered values. The categories are designed to provide flexibility when used in any protocol, especially those with cross over or repeated measure designs. This dialog box will open each time with the previously entered session number. If you wish to compute brain state measures in real time (B-Alert and Workload Classification), select the appropriate check boxes. Artifact Decontamination is essential for brain state classification and will be automatically selected. Select the definition file that corresponds to the individual being recorded. The subject number of the definition file must match the subject number entered for the current acquisition session. Artifact Decontamination and Brain State Classifications may be turned OFF in order to reduce the computational load on the computer, however, this configuration will only display and store the raw data.



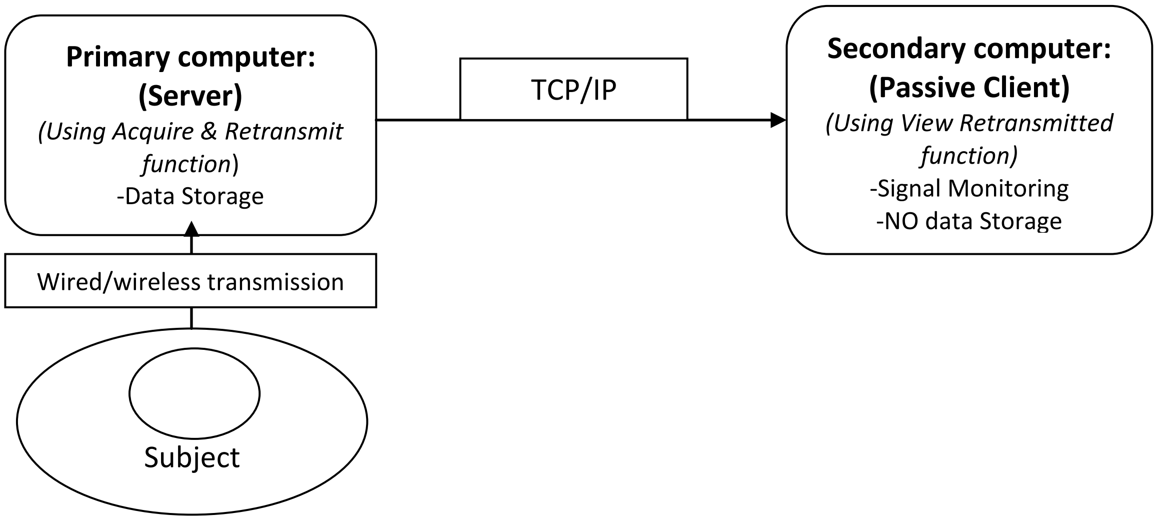
After the session number is entered, click OK. The Gauges GUI will open with the Gauges tab active by default. Click the blue play button to begin acquisition. Refer to **Chapter 6: B-Alert Gauges GUI** for additional detail during recordings.

Warning:
If the combination of Subject/Session/Group/Task numbers is identical to a previous acquisition, all files will be overwritten. A warning window will appear to prevent accidental overwrite.

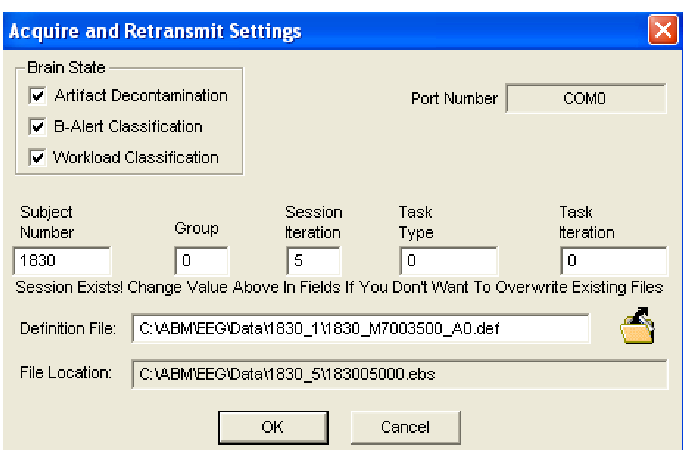
Note:
Some device configurations may not support all processed parameters.

5.4 Acquire & Retransmit

The Acquire & Retransmit function allows technicians to monitor real time data acquisition from a secondary computer, as long as primary and secondary computers are connected via TCP/IP.

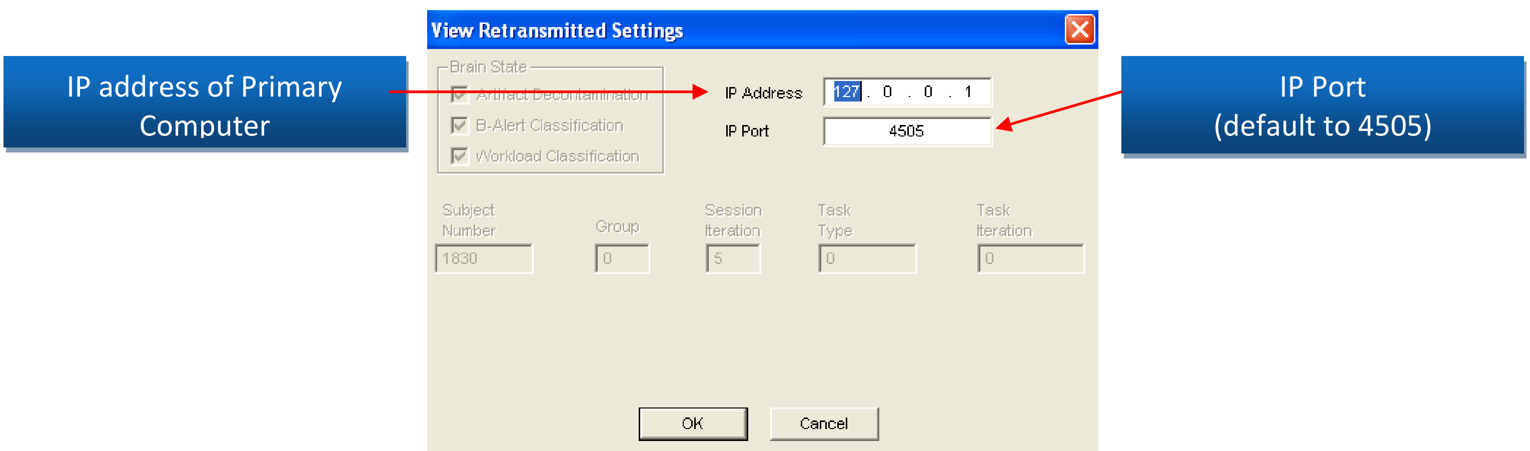


Before starting Acquire & Retransmit, plug the B-alert USB Receiver into the primary computer and turn the headset to ON. Wait for the solid green LED pattern on the headset and solid LED pattern on B-Alert USB Receiver to confirm the Receiver and Headset have connected. On the primary computer, click the "Acquire & Retransmit" icon. The Acquire and Retransmit Settings dialog will appear. Enter appropriate session information (i.e., subject number, group, etc.) and click OK to begin acquiring and retransmitting data. Select the Brain State options and corresponding definition file to generate EEG Classification measures in real time during data acquisition.



5.5 View Retransmitted

After starting Acquire & Retransmit (on the primary computer), click the "View Retransmitted" icon on the secondary computer (connected to primary computer via TCP/IP). The View Retransmitted Settings dialog will be presented. Enter the IP address of the primary computer into the IP Address field within this dialog (see the steps below to determine the IP Address for the primary computer). Once OK is clicked, the Gauges GUI program will open and the signals being acquired will be presented. **Note:** acquisition via the Acquire & Retransmit function must be started on the primary computer BEFORE the View Retransmitted function is started on secondary computer. The View Retransmitted function will not work on the same computer running the 'Acquisition' function.



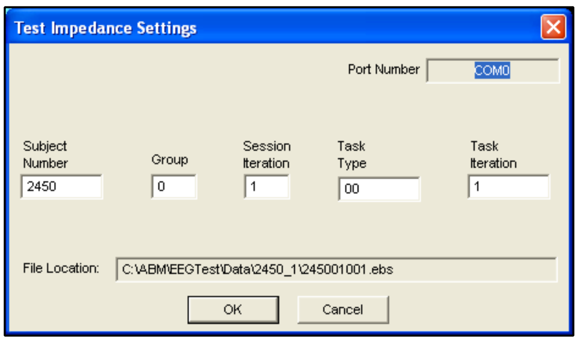
Tips for finding the IP address for the primary computer:

- Open the Start Menu and select the Run option.
- In the Run window, type “cmd”.
- When the command prompt window opens, type ipconfig and click enter.
- The IP Address will be presented.
- Enter this IP Address into the IP Address field on the secondary computer.

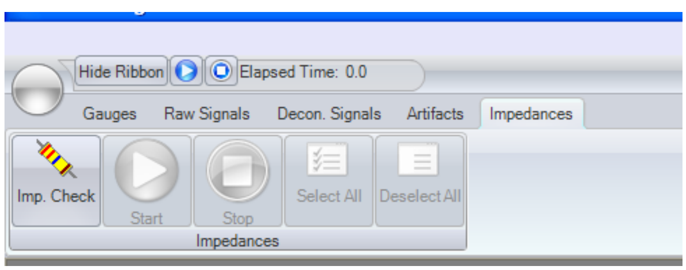
Note:
If the connection is unsuccessful:
1) Check firewall settings of both primary and secondary computer. Turn the firewall off (not recommended), or provide access to B-Alert software
2) Change the IP Port Number on the primary computer, and update the number accordingly on the secondary computer (using Settings/Configure Data Streaming menu).

5.6 Test Impedance

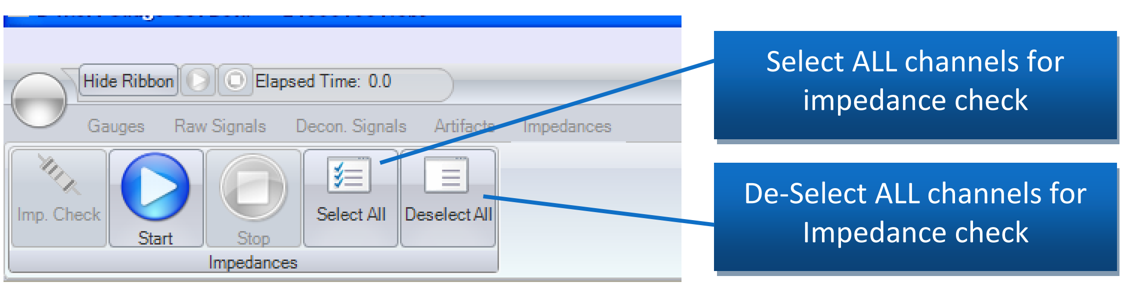
The Test Impedance function allows the user to test the impedance levels at each electrode site. Impedances measure resistance between the scalp and electrode in kΩ, where lower values reflect lower resistance and thus better conductivity between scalp and electrodes. **ABM strongly recommends using an impedance check before starting any data collection to optimize data quality**. Before starting Test Impedance, plug the B-alert USB Receiver into the PC and turn the headset to ON. Wait for the solid green LED pattern on the headset and the solid LED pattern on the B-Alert USB Receiver to confirm the Receiver and Headset have connected. When the "Test Impedance" button is clicked, the Test Impedance Settings dialog will open. Enter the session number and click OK.

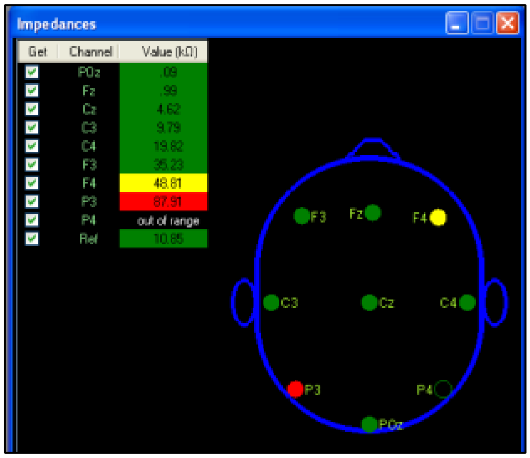


The Gauges GUI will open with the Impedance Tab active by default. Click the "Imp. Check" button.



Click the large blue "Start" button to begin the impedance test.





Impedance values < 40kΩ will be highlighted in green, values 40kΩ - 80kΩ will be yellow, and impedance values > 80kΩ will be red (indicating that the sensor is outside the acceptable range). Impedance values will typically decrease for the first 30-45 min after headset application. For more tips on lowering impedances, refer to the Hardware Manual. ABM recommends sensor impedances below 40kΩ for optimal data quality, but all B-Alert users should determine a standard impedance threshold for data collections to maintain data quality across subjects. Impedances higher than 40kΩ (yellow) can still collect good quality EEG, and thus may not be reason to exclude a participant from continuing to collect. If high impedances are seen across *all* EEG channels, try replacing the mastoid sensors before troubleshooting each EEG site -- high Reference impedance will impact *all* EEG impedance measurements. Users can down select and customize which channel(s) will be checked by using the check boxes in the "Get" column, or the "Select All" and "De-Select All" buttons in the ribbon (not available for X4).

The following output files are generated during an impedance test; these files are useful for technical support, but not for data analysis:

- *xxxxxxxxx.ebs_0_35_12_impedance_results.csv:* This CSV file will contain the impedance values from each impedance test performed. If repeated impedance tests are performed for the subject, a unique CSV file will be saved each time, organized by system time.
- *xxxxxxxxx.ebs_0_35_12.ebs:* An impedance EBS file is saved in the subject folder for each impedance test performed. The system time is included in the file name to allow simple file tracking.

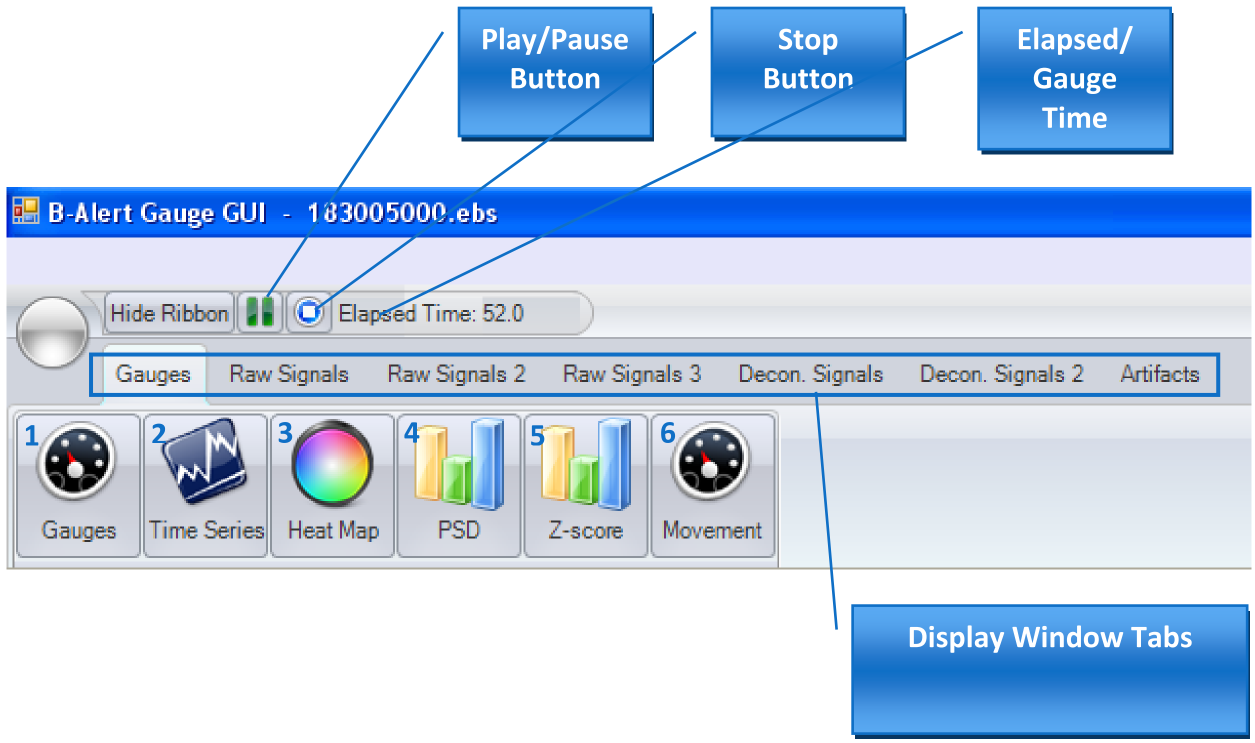
5.7 Acquire B-Alert Baselines

The Acquire B-Alert Baselines function allows the experimenter to run the three B-Alert Baseline tasks required for definition file (.def file) creation: 3-Choice Vigilance task, Eyes Open, and Eyes Closed. See **Chapter 7** for more details.

Chapter 6: B-Alert Gauges GUI

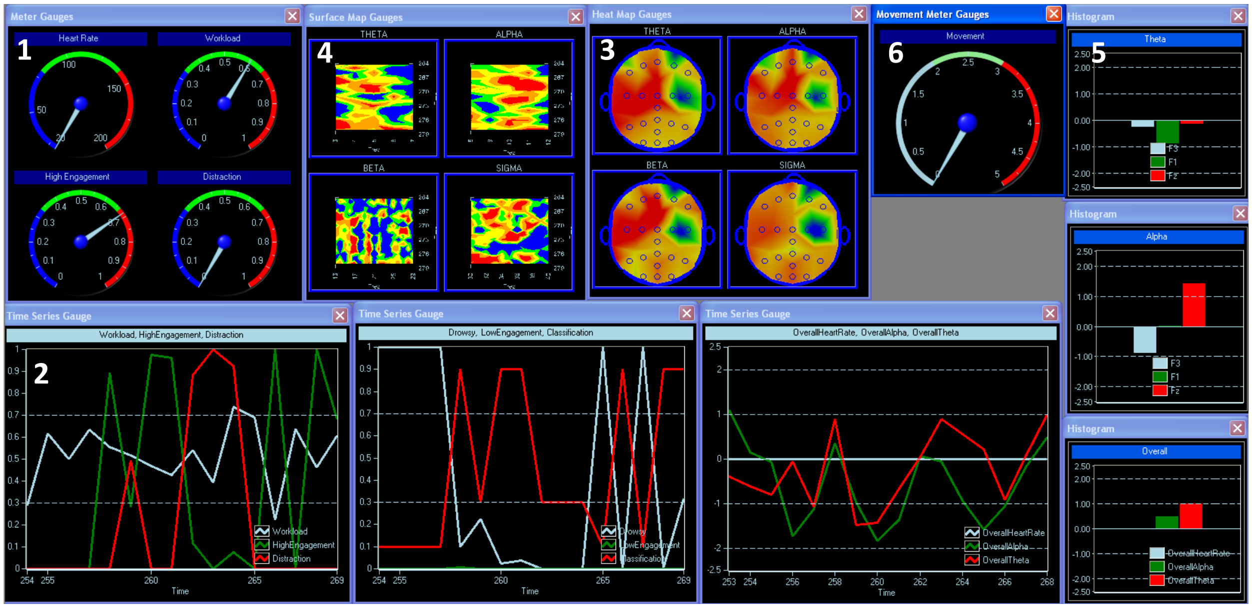
6.1 B-Alert Gauges GUI Overview

After initiating a data acquisition using the "Acquisition" or "Acquire & Retransmit" action button, the B-Alert GUI will be loaded. The B-Alert GUI visualizes raw and processed physiological signals in a range of formats to provide a comprehensive visualization of physiology in real time and offline.



6.2 Gauges Window

The gauges are fully customizable to fit the requirements of the user and optimize information display. The easy-to-read gauge and time series windows present ABM's second-by-second B-Alert classification metrics: Engagement, Workload (not available with X4), Drowsiness, and Heart Rate. Heat maps display EEG power spectral densities (PSDs) in both spatial and temporal maps for the traditional Hz bands (i.e., Beta, Alpha, Theta, Sigma).



1. **Meter Gauges:** Show the B-Alert classifications (Workload, High Engagement, and Distraction) averaged on a 3-second window, and Heart Rate.

2. **Time Series:** Shows z-scored values (updated every second) in a 15-seconds window. Three views are selectable: (1) Workload, High Engagement, and Distraction (default); (2) Drowsy, Low Engagement, and Classification; and (3) Overall Heart Rate, Overall Alpha, and Overall Theta.

3. **Heat Map:** Shows 4-seconds averaged distribution of PSDs for the specified EEG band across the scalp. The PSDs are computed from decontaminated data (if available), smoothened using Kaiser-window, and averaged across 3-epoch overlays. Default bands are: Theta (3-7 Hz), Alpha (8-12 Hz), Beta (13-29 Hz) and Sigma (30-40 Hz).

4. **Surface Map:** Shows z-scored time history (5-sec) of the PSDs of individual bins calculated across all the channels.

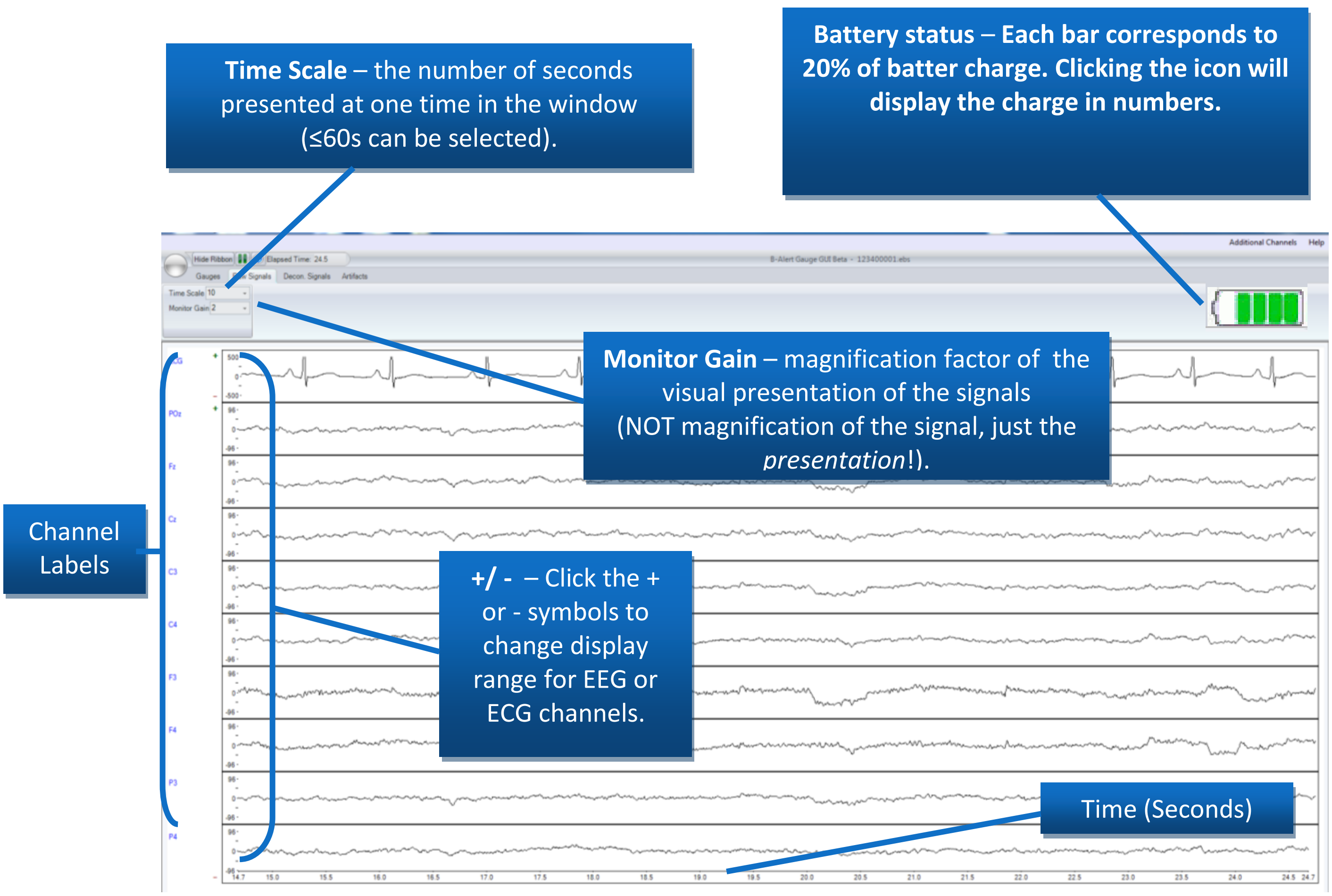
5. **Z-Score:** Shows z-scored second-by-second values of EEG Bands for specified electrodes in histogram format. Three default views are available: (1) F3, F1, Fz for Theta band; (2) F3, F1, Fz for Alpha band; and (3) Overall Alpha and Theta across all channels and HR.

6. **Movement:** Shows movement scale computed from the change in the dominant angles of the 3-axis accelerometer.

Note:
The availability of the gauges depends on the type of the device and brain state processing selected. For example:
1) Workload classification is not available for the B-Alert X4.
2) If no brain state classifications are selected in Acquisition Settings, the corresponding gauges will not be available.
3) If Artifact decontamination is not selected in Acquisition Settings, PSDs will be computed from raw data.

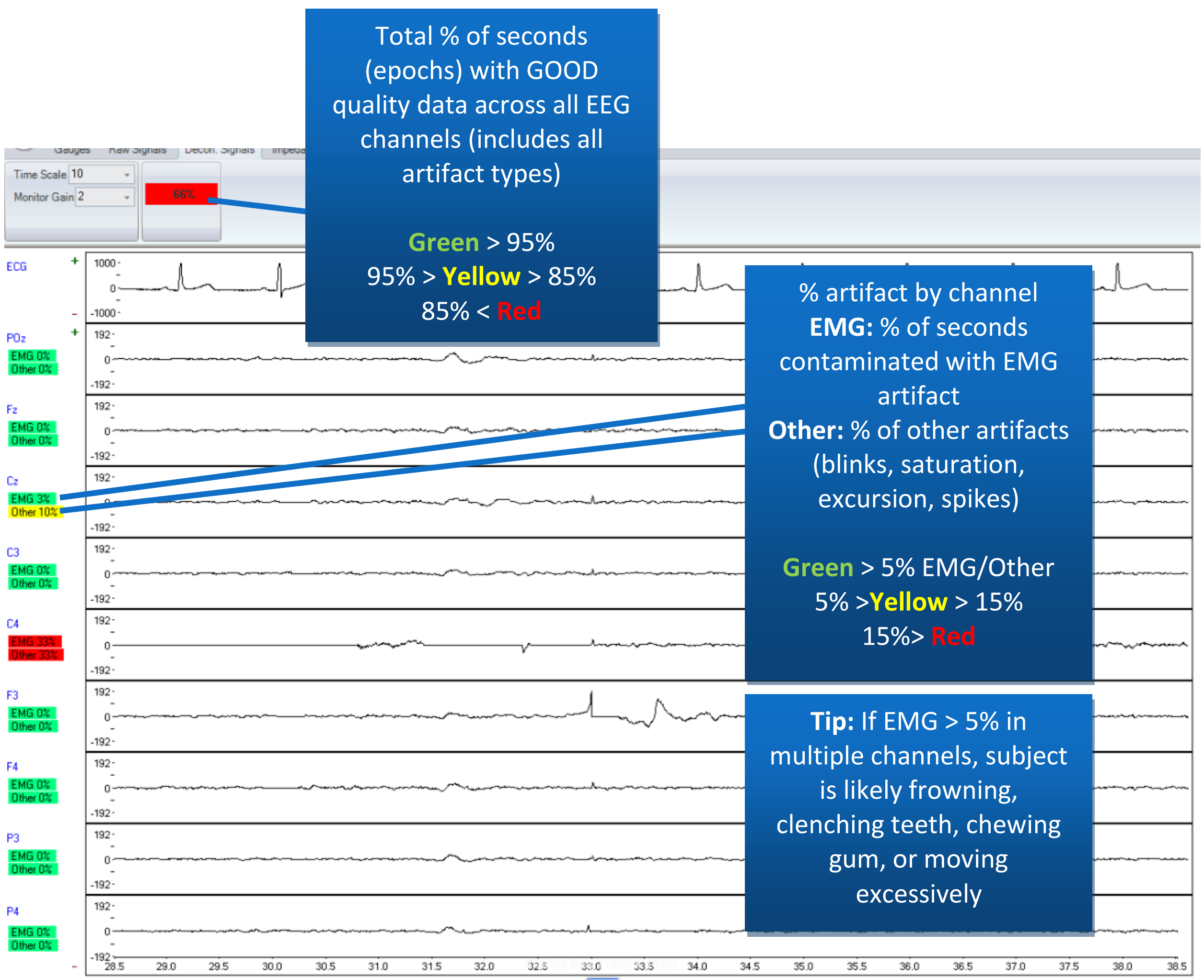
6.3 Raw Signals Window

The Raw Signals window displays raw data signals, as shown below.



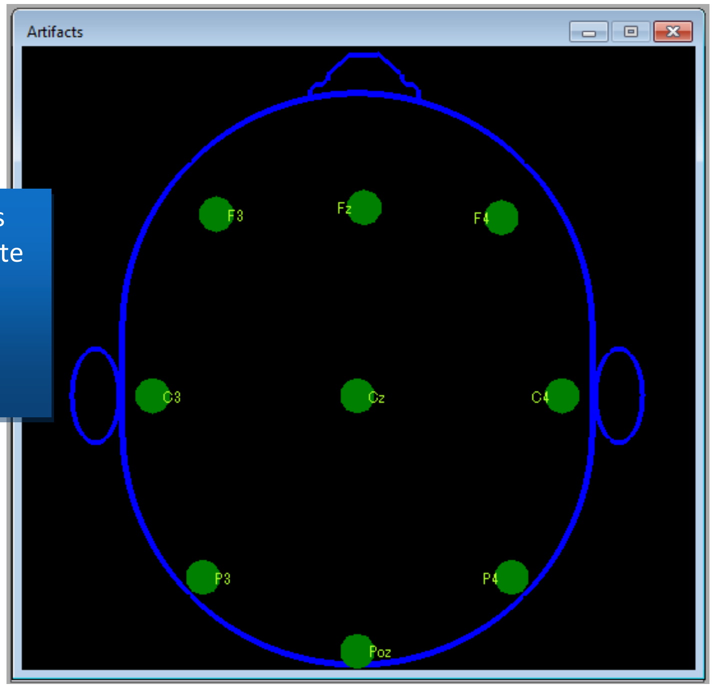
6.4 Decon. Signals Window (Decontaminated Signals)

The Decon Signals window visualizes EEG signals using ABM's validated Artifact identification and decontamination algorithms which identify and remove 5 artifact types: EMG, eye blinks, excursions, saturations, and spikes. The use of overlayed windowing and data computation results in an approximately 2.5 - 3 second delay in the decontaminated signals. Depending on the amount of noise in the signal and the number of channels in the device, the decontaminated signal could lag up to several additional seconds. For additional details regarding the artifact identification and decontamination procedures, refer to **Appendix A**: Outputs Guide. Use of color coding and displayed running percentages provide users with a real time visualization of data quality. The time scale, monitor gain, and other viewing settings in the Decon Signals window are the same as those on the Raw Signals tab. ABM does not employ any artifact decontamination procedures for the ECG channel. ABM's data quality indicators (color and percentages) are built for ABM's EEG classifiers--- these values may not be appropriate data quality measures for some EEG applications.



6.5 Artifacts Window

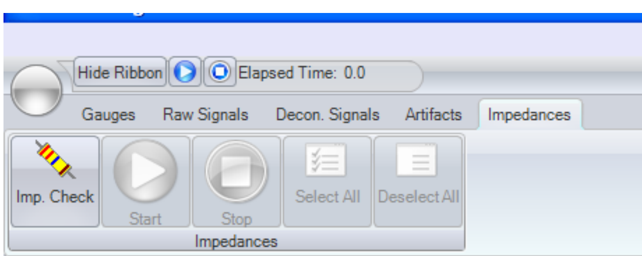
The artifacts window displays the color-coded artifact percentages for each sensor site.



Artifacts Window -- Displays artifact % in color by sensor site
Green > 5% EMG/Other
5% >**Yellow** > 15%
15%> **Red**

6.6 Impedances Window

The Impedances Window allows users to check data quality prior to initiating a data acquisition.



Imp. Check – This feature is not available while acquisition is running. If acquisition has not been started or is stopped, user can initiate an impedance check by clicking the Imp. Check button, then the "Play" button.

6.7 Markers

The following keyboard shortcuts allow the user to register ‘Start’ and ‘Stop’ markers in the data, indicating regions of interest:

- Shift + S – Start marker (GREEN)
- Shift + E – Stop marker (RED)

In the Gauges tab, the markers can be used in the Time Series window. In Raw and Decon data tabs, the EEG data at the beginning of the closest epoch will be marked. The markers are saved both in a readable ‘.mrk’ file, as well as in the EDF file. The markers can be visualized in EVA during offline analysis.

Chapter 7: Acquiring Baselines for B-Alert Classifications

7.1 B-Alert Baseline Acquisition

The acquisition of baseline data is used to create the individualized EEG profiles required for the B-Alert cognitive state metrics (i.e., B-Alert model and Workload). The “Baseline” Alertness and Memory Profiler (AMP) obtains 5 min each of: a 3-choice psychomotor vigilance task (3CVT), eyes open (EO), and eyes closed (EC). The “Drowsy” AMP extends the 3CVT to 20-minutes, which allows users to profile individuals unable to remain within a normal performance range during the 3CVT task, a predictor that may result in abnormal B-Alert classifications. Typically, baseline data only needs to be obtained one time for each individual if performed on a healthy, rested subject. Additional session iterations are recommended, however, when pre- and post-conditional changes are made.

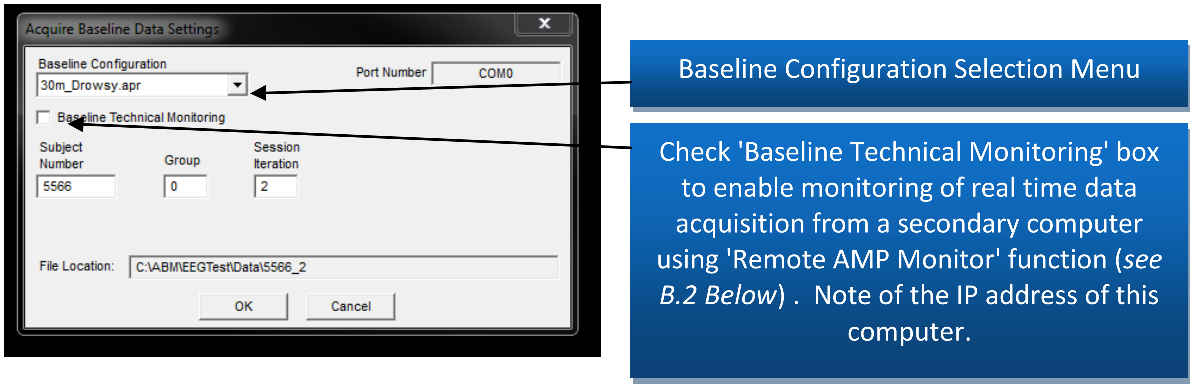
Baseline = ~ 15 minutes Drowsy = ~ 30 minutes

Baseline configuration	15m_Baseline.apr	30m_Drowsy.apr
Task 1	3C-VT (~7 min)	3C-VT (~20 min)
Task 2	EO (~6 min)	EO (~6 min)
Task 3	EC (~6 min)	EC (~6 min)
Total Run Time	~19min	~32min

7.2 Steps for B-Alert Baseline Acquisition

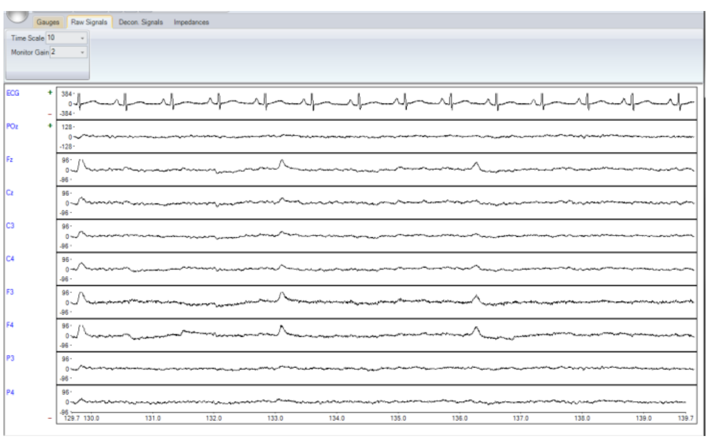
1. Acquire B-Alert Baselines

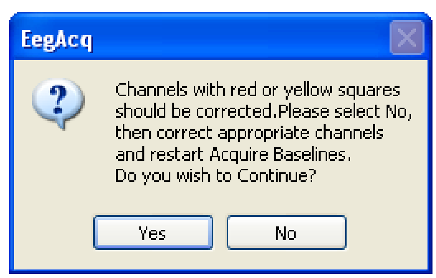
Click the "Acquire B-Alert Baslines" icon to select the desired baseline configuration. The Acquire Baseline Data Settings dialog will open. Select the desired baseline configuration from the drop down menu and enter the subject number (XXXX), group number (G), and session iteration number (Y). The session task type (WW) and task iteration (N) values will be generated automatically for all Baseline sessions. The following naming conventions will be used for data storage:



- Impedance Check XXXXGY931.ebs
- Quality Check XXXXG1000.ebs
- 3-CVT data – Baseline XXXXGY201.ebs
- 3-CVT data – Drowsy XXXXGY231.ebs
- EO data – Baseline/Drowsy/ACES XXXXGY111.ebs
- EC data – Baseline/Drowsy/ACES XXXXGY121.ebs

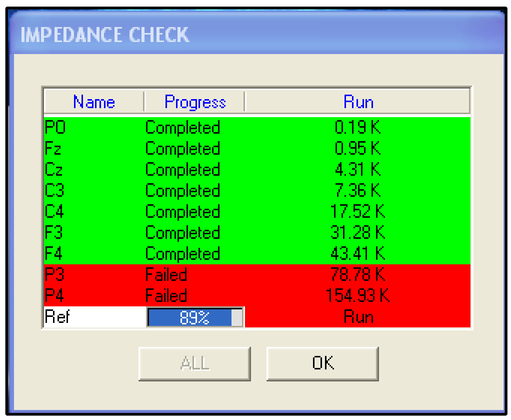
After entering the session information, BAA will automatically perform a 60-second signal quality/artifact check (press the blue PLAY icon to view data during 60 second check). During this time, the signals presented on the screen should be visually inspected to see if EEG, EMG, and ECG signals are properly presented. If there are signals that appear abnormal, make any necessary adjustments.





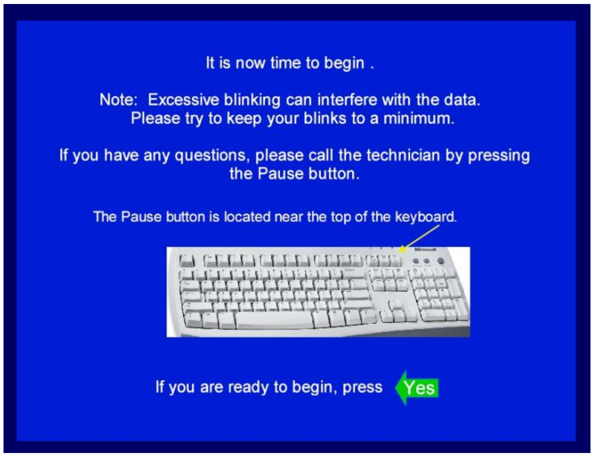
After a quality check is performed, an impedance check will be initiated. The following window will be shown; press the **left arrow** button on the keyboard to begin the impedance check.

During the Impedance Check the following window will be shown.



Channels highlighted in green have passed the impedance check. Channels highlighted in red have “failed” the impedance check, and the window indicating that sensors need to be adjusted will appear:

Click **F11** to exit from this screen and return to the impedance check window. Click the ALL button to repeat the impedance test or click OK to continue to the AMP session. After the impedance check, the subject is ready to begin.

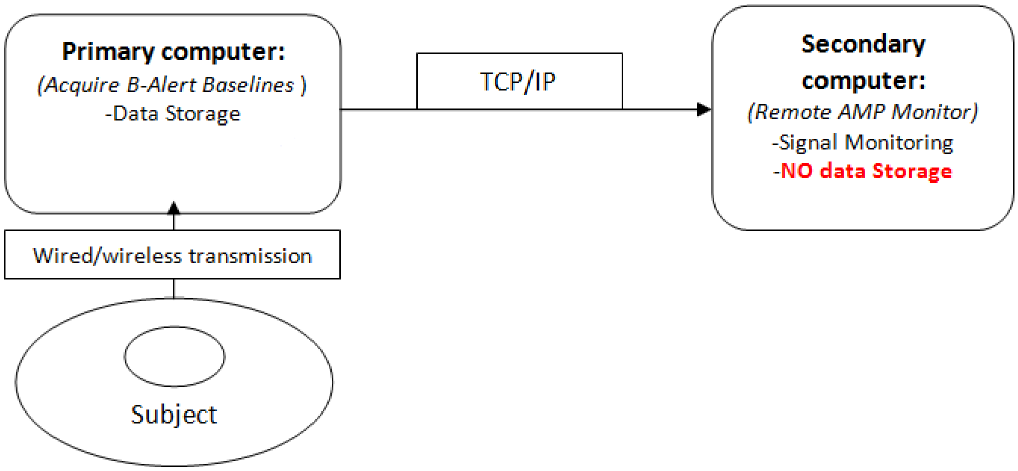


Note:
All impedance values should have passing results before the AMP is started. Refer to the hardware manual or strip labeling for the electrode site naming convention.

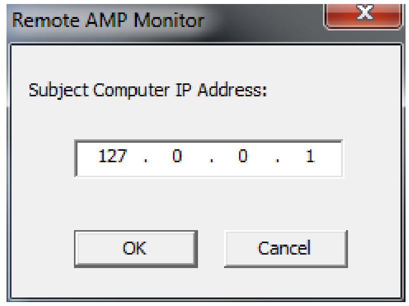
If impedance values have been previously checked using the Test Impedance action button, you may choose to bypass this built-in impedance check by pressing OK at any time.

2. Monitoring Signal During B-Alert Baselines (Available only for X4 & X10)

When possible, ABM strongly encourages technicians to monitor the data quality of signals throughout the B-Alert Baseline using the 'Remote AMP Monitor' function. This function acts identical to the 'View Retransmitted' function, where technicians can configure the software to view the live physiological data on the computer running the B-Alert Baselines over TCP/IP. **Note:** Data on secondary computer will be visualized ONLY (no data storage).



To launch the Remote AMP Monitor, go to the Operations menu at the top of the main B-Alert Control GUI and select Remote AMP Monitor. R*emote AMP monitor function must be launched after the testing has started (during training of 3-CVT), following the 60 second data quality check and impedance check.*

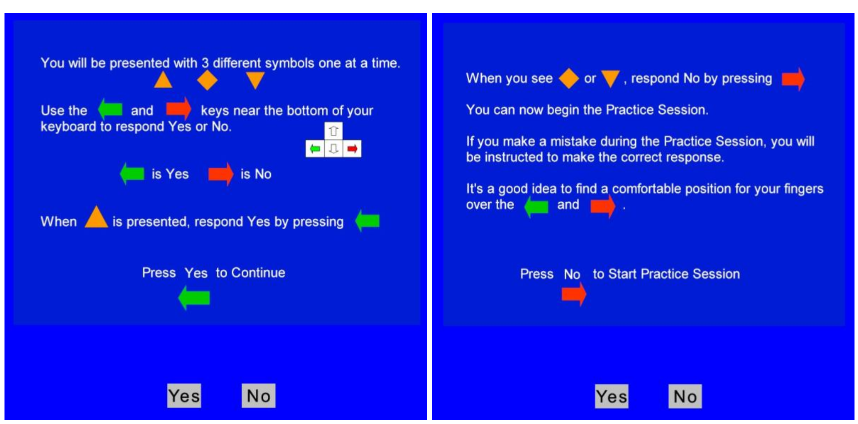


A 'Remote AMP Monitor' pop-up window will appear with a text box to allow users to enter in the IP address of the primary computer (i.e., the PC running Acquire B-Alert Baseline). Enter the IP, then click 'OK' to launch the monitor. The Remote AMP monitor display utilizes functions from an older version of the B-Alert Acquisition software, so the signal presentation will look different than the Gauges/Heat map window, but it displays the same information.

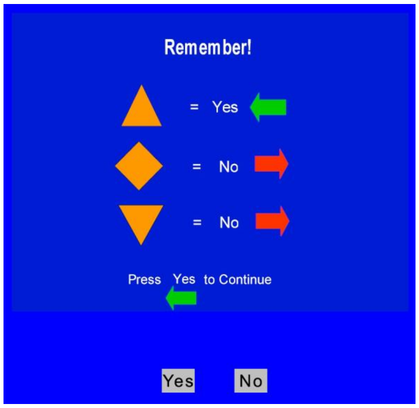
3. Completing the AMP tasks

The subject will be prompted to complete at least three neurocognitive tests. The standard session length for EO and EC is 5 min, with additional time appended if the user fails to respond consistently (suggesting they fell asleep, and thereby distorting the baseline measures).

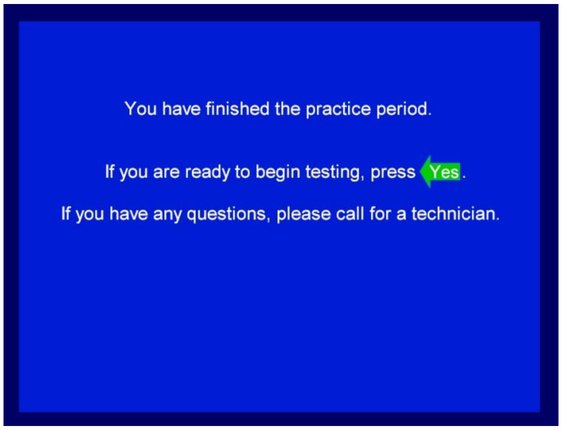
a. 3CVT: After the instructions are presented, the 3CVT begins with a Practice Session:



During the practice session, AMP will alert the subject when an incorrect response is made to insure that he/she understands the task.

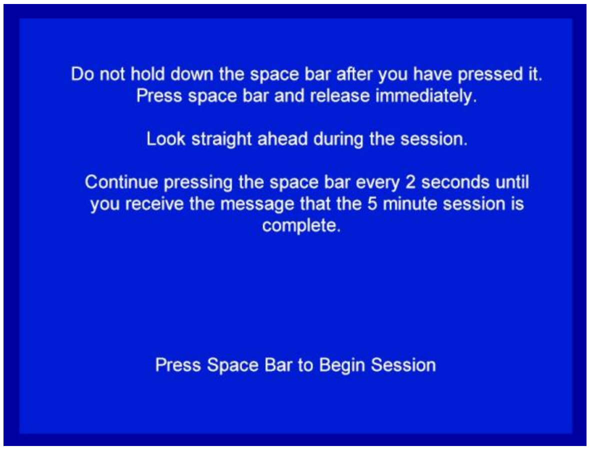


As soon as the user demonstrates that they understand each of the responses, the practice session will terminate and the testing session will begin.

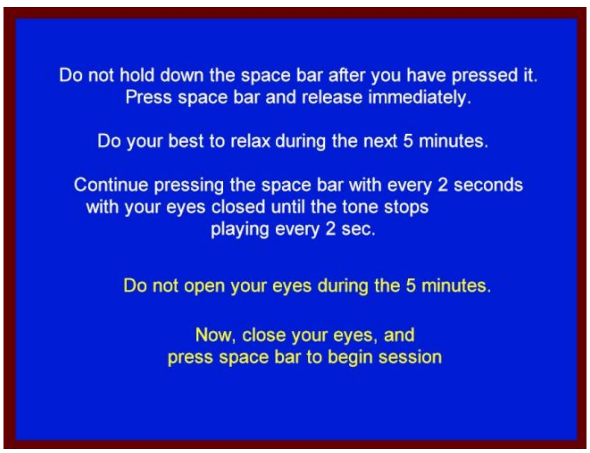


The length of the 3CVT (after the practice period) will either be 5- or 20-minutes long, depending on the baseline type selected. During the first 5-minute period, stimuli appear frequently and require a high state of alertness. The inter-stimulus intervals are extended in the remaining 15 minutes of the 3CVT in order to better identify individuals who are unable to remain engaged (i.e., excessive daytime drowsiness or other sleep related disorders). Subjects who are unable to sustain performance within a normal range across the 3CVT will be flagged as having an invalid baseline session.

b. **EO:** The Eyes Open test begins with the following instructions.



c. **EC:** The Eyes Closed test begins with the following instructions.



After completing the AMP, a completion dialogue will appear.

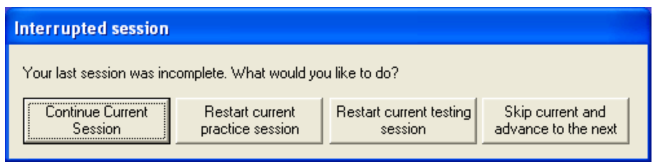
Once acquired, the AMP session files will be stored in the subject's folder. The definition file needed for B-Alert classifications will also be automatically generated and placed in the subject's folder. The .def file is required for generating EEG classification metrics in Real-Time during acquisition or during offline data analysis.

7.3 Acquisition Troubleshooting

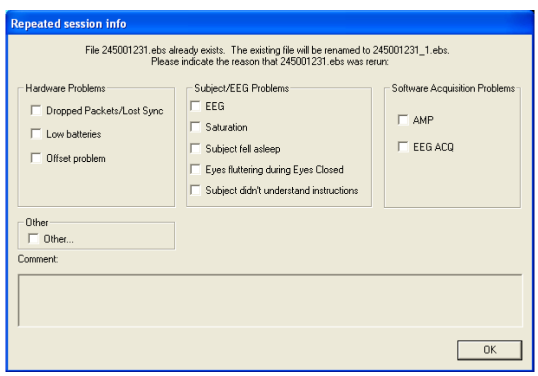
During any of the three tasks in B-Alert Baseline, the technician may interrupt the session using three key controls: ***F3***, ***F8***, and ***F11***.

F3 - takes the subject to the very end of the *entire AMP session* and is available for use only during the instruction windows.

F8 - allows the technician to interrupt the subject only during Testing Sessions. This window will then appear:



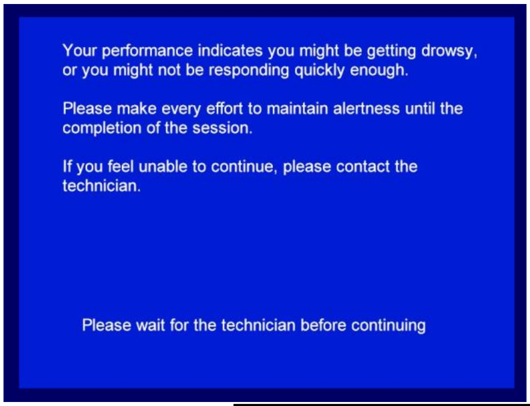
At this point, the technician can choose the appropriate action. If the technician chooses the option to restart the current testing session, the following window will then appear:

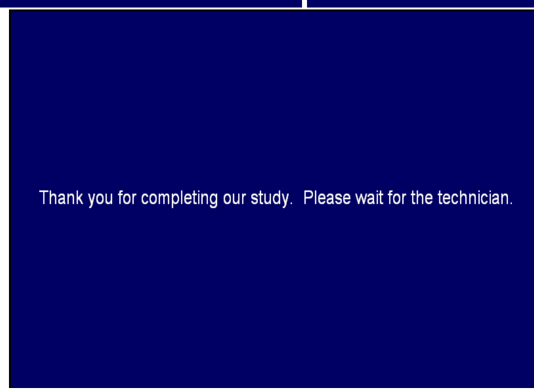


In order to recollect data, the technician must make note of any problems that occurred during the testing, i.e., drowsiness, low batteries, EEG, etc.

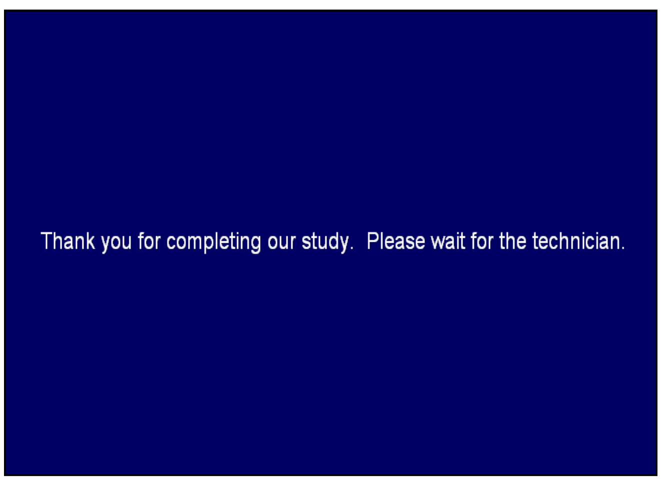
F11 - is used to get out of a "Technician Requested" window, when a subject presses the Pause button during testing, when subject is kicked out of a task due to a lack of response, or to exit out of the last screen of the Baseline.

The following are examples of when to use this button:





Upon completing the AMP session, this screen will appear:

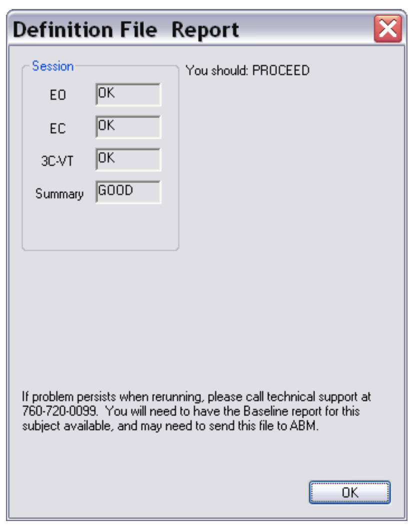


Once the technician exits out of this screen using *F11*, the main screen of the B-Alert Control GUI will appear on the subject's computer and completion status will be informed by a dialog.

Note:
After completing any baseline, the B-Alert Software will automatically run a data quality and performance check. Following these checks, the software will create a definition file. Creation of the baseline file may take up to 10 min, during which time the software will appear unresponsive.

A "Definition File is created" pop up window will notify the user when processing is complete (5 - 10 min), and baseline file and summary report are generated.

If the definition file and baseline report generation are not automatically triggered, or fail for some reason, you can create them offline by selecting the "Create Definition File" button and following the instructions in **Chapter 9**. The dialogue summary (xxxxx_BaselineReport.csv, where xxxxx indicates subject/session ID) will also be created when invoking the action offline.



If any of the data is determined to be 'bad', the reasons for classifying the definition file as such and suggested action will be presented in this box. The Status of each task is based on a three part check: user performance, EEG data quality, and EEG classification breakdown. If any task(s) are identified as being marginal or bad, ABM recommends re-running the flagged tasks if time permits. After completing the re-run tasks, users can place all three valid tasks into the same folder, and then create a .definition file (.def) on those tasks. These performance and classification thresholds are designed to notify users when ABM identifies an EEG baseline that does not behave within normal ranges, indicating that the .def file may not provide valid outputs. Users are encouraged to determine whether or not to use a .def file and classification.

Chapter 8: Advanced Settings and Operations

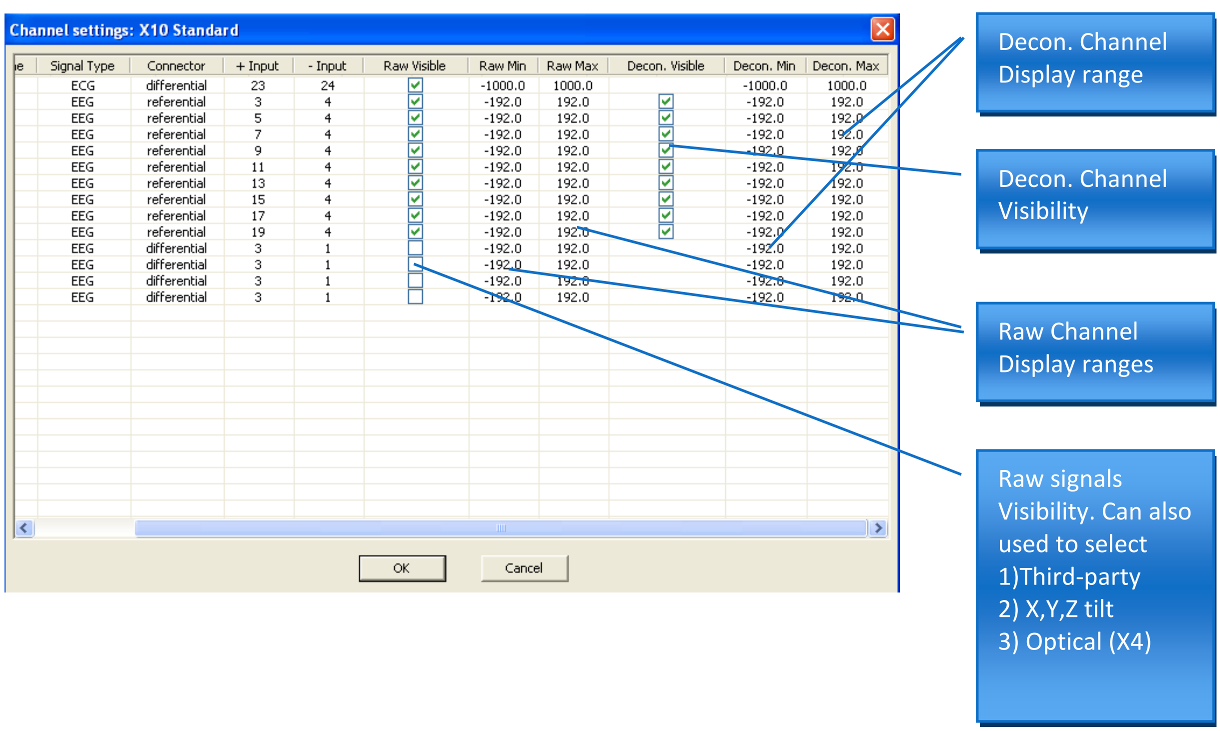
8.1 Taskbar

The settings bar can be hidden by deselecting the settings bar option in the view menu. If the settings bar option is selected, the settings taskbar appears as shown.

1. **Find Port:** Selecting "Find Port" will locate and assign the serial port for communication between the headset and the B-Alert Control GUI. Before clicking 'Find Port,' make sure the headset is connected to B-Alert Receiver by checking the headset for a solid LED light pattern. *Note:* All operations invoke "Find Port" automatically, thus clicking the Find Port button is optional.

2. **Headset Config:** Select type of headset (in most cases this will be automatically selected; when a wrong configuration is selected the user will be warned).

3. **Channel Map Ellipsis Button:** Adjust and modify signal presentation options, such as Range, channel visibility, etc.

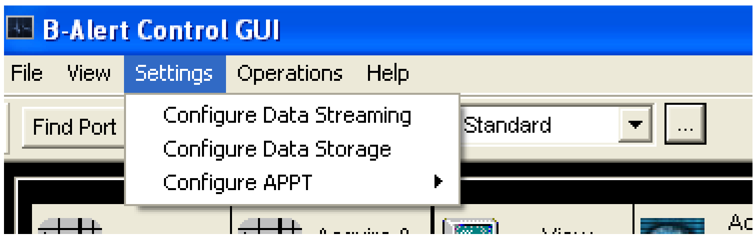


Additional channels that can be selected are as follows:

- Third-party data – events send from third-party software to ABM receiver (ESU)
- X, Y, Z tilt – output of 3-axis accelerometer in angles
- Optical – IRED signal used to derive pulse (available only in the X4)

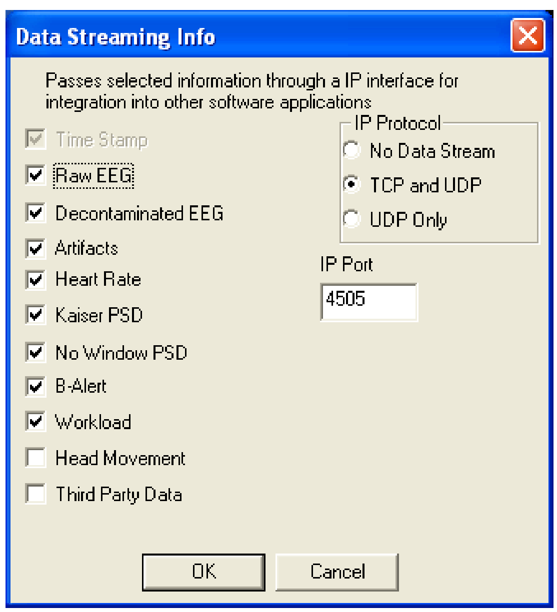
8.2 Settings

The Settings menu can be used to configure: 1) Data Streaming, 2) Data Storage, or 3) APPT:



1. Configure Data Streaming

Selecting the Data Streaming option opens the Data Streaming Info window:



A. No Data Stream

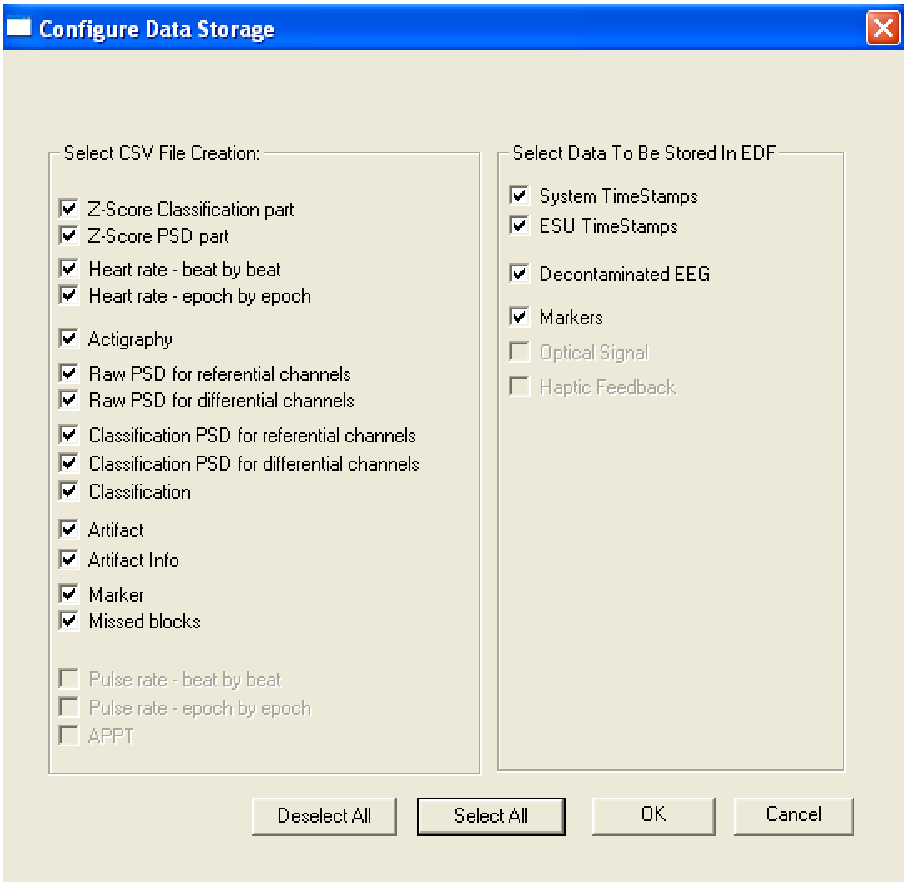
B. TCP and UDP – This protocol allows the user to select from the options listed on the left side of the Data Streaming Info window to be passed via TCP. When this option is selected, the time stamp information will be passed via UDP, while the selected data is transmitted via TCP:

a. **Time Stamp**: Elapsed time for the current session (seconds and milliseconds).
b. **Raw EEG**: Raw EEG signal.
c. **Decontaminated EEG:** EEG signal after removal of artifacts as identified by ABM decon algorithms.
d. **Artifact:** The start and stop times of artifacts identified in the EEG.
e. **Heart Rate:** the beat to beat heart rate and variability.
f. **Classification PSD**: Power Spectral Densities from the 1-40 Hz bins of each channel, smoothed using a Kaiser Window (See *Appendix A: Data Outputs Guide* for more details). The PSDs are also averaged across 3-epoch overlays.
g. **Raw PSD:** PSD computed without decontaminating artifacts and without applying Kaiser Windows. The PSDs are still averaged across 3-epoch overlays.
h. **B-Alert Classification:** Probabilities of High Engagement, Low Engagement, Distraction, and Sleep Onset.
i. **Workload Classification**: Probability of High Workload.
j. **Head Movement**: Accelerometer data.
k. **Third Party Data:** Third-party events send to ABM receiver (ESU).
l. **IP Port:** Designates the IP Port that the server opens for all clients to connect.

C. UDP Only – passes only the **Time Stamp** data via UDP.

2. Configure Data Storage

This option allows users to configure which ABM output files are created during Data Acquisition (in both 'Acquisition' and 'Acquire & Retransmit'). The B-Alert SW is defaulted to save all output types, but users have the option to deselect outputs if desired.

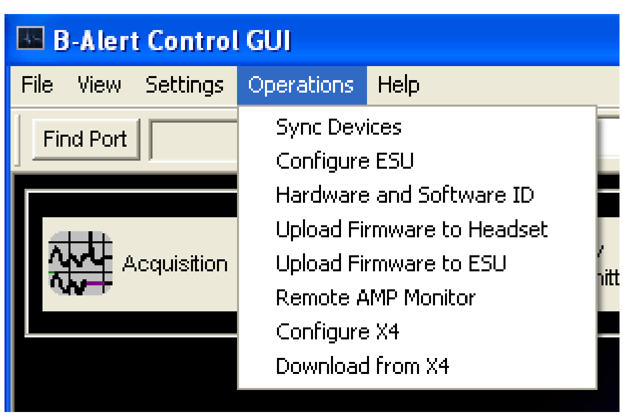


3. **Configure APPT**

Reserved for ABM internal R&D.

8.3 Operations

The operations menu can be used to sync ABM devices to an ABM receiver, configure an ABM receiver, view hardware details, upload firmware, and invoke remote monitoring of an AMP.

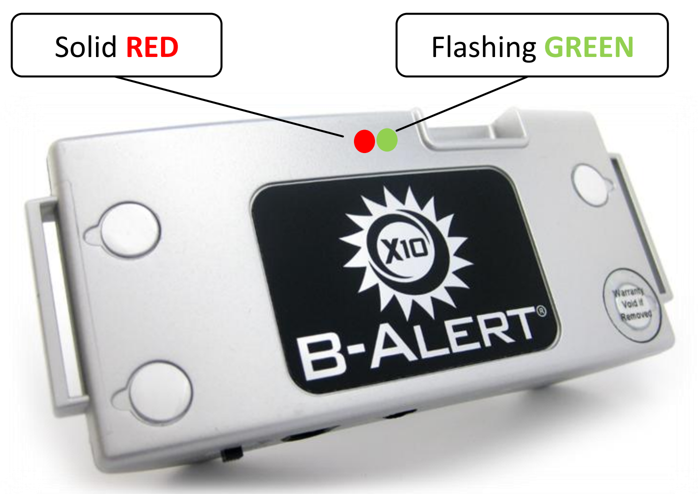


1. Sync Devices

The B-Alert headsets are shipped paired to either a B-Alert Dongle or an ESU Multichannel (ESU-MC). If the pairing is lost, the devices must be synced again using the "Sync Device" function in the Operations Men

a. Plug the B-Alert ESU Receiver into your PC. *Note*: Ensure that any other ABM Headsets or B-Alert ESU Receivers are turned off and unplugged before attempting to sync a USB device and headset.

b. Turn the B-Alert headset to ON. The Red LED will turn on for the first 3-4 seconds, followed by 10 seconds of Green LED flashing. Wait until the headset LED pattern is Flashing Green and Solid Red before proceeding to the next step:

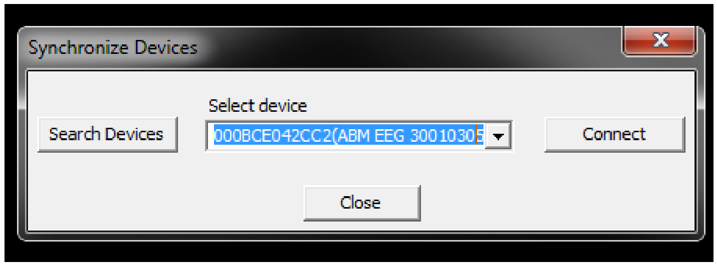


c. In the Operations menu, click on "Sync Devices".

d. Click the "Search Devices" button and wait. It will take 45-60 seconds for the USB device to search for other Bluetooth devices in range.

e. After the search has completed, all Bluetooth devices identified in range will appear under the "Select Device" drop down menu.

f. Look for the B-Alert headset. The device should have a 12 digit BDA address followed by: (ABM EEG XXXXXXXXXXX). Example: *000BCE042CCA(ABM EEG 300103056):*



g. Click "Connect" and wait for the pop-up window indicating that the headset has connected: "Device connection succeeded. Please restart device."

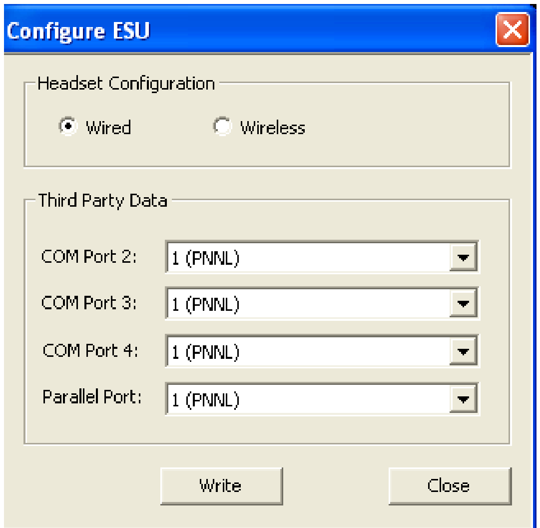
h. Click 'OK,' then turn the Headset OFF.

i. Unplug the B-Alert ESU Receiver, and then re-plug B-Alert ESU Receiver.

j. Turn headset back ON; wait 5-10 seconds for the Green LED on headset to turn Solid Green, signaling the headset has synced.

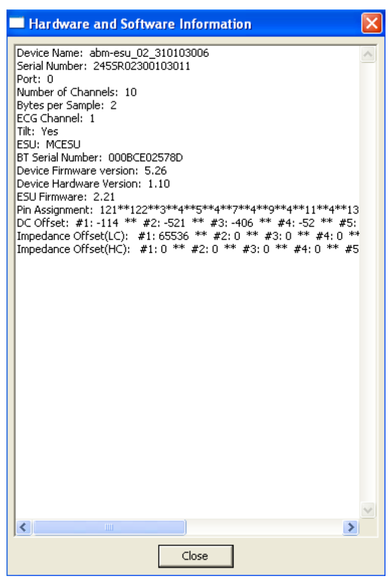
2. Configure ESU

Users with the ESU-MC have the option to switch between wired and wireless data collection modes, as well as to configure the serial and parallel port settings. Please refer to **Chapter 10** for additional details.



3. Hardware and Software ID

The 'Hardware and Software ID' option allows users to check the HW settings of the B-Alert Headset and B-Alert ESU Receiver (B-alert Dongle or ESU-MC):



Note:

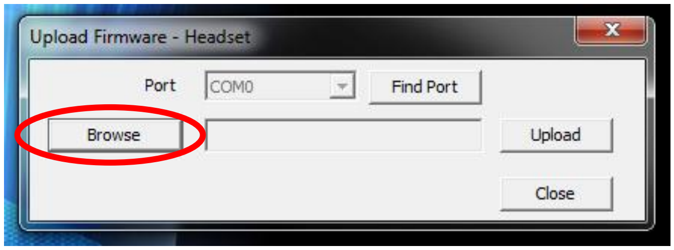
The information in this window is valuable for debugging purposes. If possible, please send a snapshot of this window during all hardware-related correspondence with ABM.

4. Upload Firmware to Headset

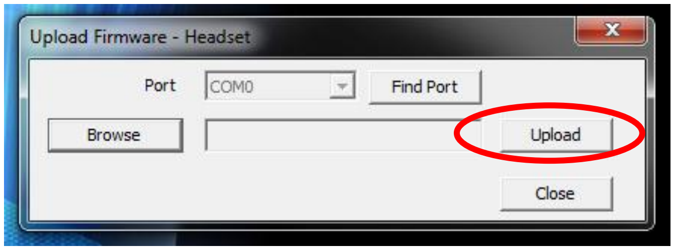
The "Upload Firmware to Headset" option allows users to update the headset firmware using a B-Alert ESU Receiver. The procedure is as follows:

a. Connect the headset to the B-Alert ESU Receiver (the solid Green LED confirms connection). Select "Upload Firmware to Headset" from the Operations menu.

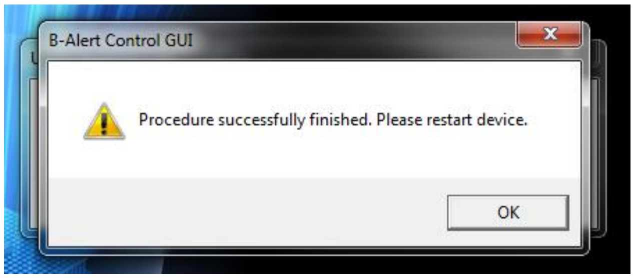
b. Click the 'Browse' button to select path to the firmware .txt file:



c. After selecting the Headset firmware .txt file, click the 'Upload' button:



d. Wait 20-30 seconds. A pop-up window will appear to notify you that the firmware upload was successful:



e. Finalize the firmware upload by restarting the Headset (turning off/on).

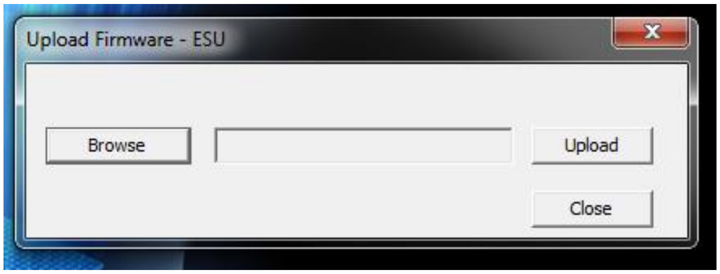
Note:
For X4, firmware cannot be uploaded wirelessly (hence "Find port" is disabled). Please connect the device to the computer using a USB cable and follow the same procedure.

5. Upload Firmware to ESU

The "Upload Firmware to ESU" option allows users to update firmware on B-Alert ESU Receivers. The procedure is as follows:

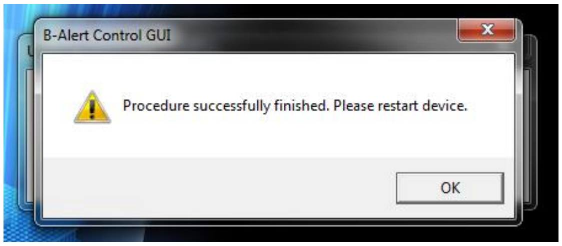
a. Plug in the B-Alert ESU Receiver. Select "Upload Firmware to ESU" from the Operations menu.

b. Click the 'Browse' button to select the path to the firmware .hex file:



c. After selecting the B-Alert ESU Receiver firmware .hex file, click the 'Upload' button.

d. Wait 15-30 seconds. A pop-up window will appear to notify you that the firmware upload was successful:



e. Finalize the firmware upload by restarting the B-Alert ESU Receiver (unplugging/re-plugging).

6. Remote AMP Monitor

Remote AMP Monitor is used to view signals remotely during AMP sessions. Refer to **Chapter 7** for more details.

7. Configure X4

ABM X-4 devices can work in two modes: (1) Recorder Mode (Stores data to internal SD card), and (2) Monitor Mode (transmits data via Bluetooth to the PC). The radio in the device is switched off during the Recorder Mode, thus reducing battery consumption. The X4 can work continuously for up to 15 hours in the Recorder Mode. The ‘Configure X4’ Menu can be used to switch between the two modes.

Note:
The X4 can be updated only via the USB cable. It is also required to plug in the ABM Receiver while using the Configure X4 interface so that the Bluetooth address of the receiver can be registered and stored in the device. The user may bypass the ‘Sync procedure’ if ‘Configure X4’ was used.

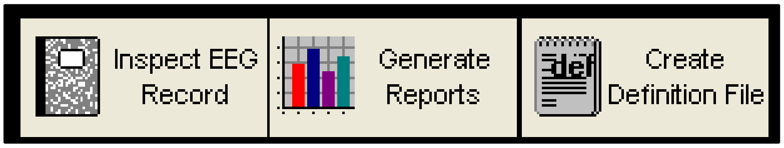
8. Download from X4

The user can download data stored in the internal SD card (supported only in X4) using ‘Download from X4’ interface. All the sessions in the SD card will be displayed and the user can download the sessions individually (Download button) or collectively (Download All button). The data will be stored in edf format, which can be used to generate reports, play/view offline, etc. The Format button can be used to erase all data in the SD card at the beginning of a new session. The Refresh button automatically selects the drive that windows registers for the SD card.

Note:
The data can be downloaded only via the USB cable.

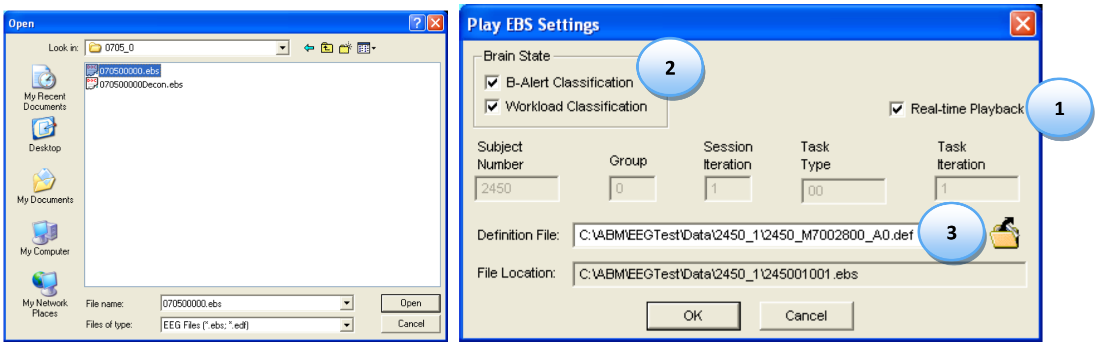
Chapter 9: Data Analysis and Review

The B-Alert Acquisition Software has 3 offline action icons which are used for off-line data analysis, after data acquisition:



9.1 Inspect EEG Record

To begin Playback, click the "Inspect EEG Record" icon. This will open a browse window. From the browse window, select the desired EBS file and click the Open button. The Play EBS Settings dialog will then be presented. Select the playback mode by either checking or unchecking (for off-line playback) the Real-Time Playback check box.



1. **Playback**: Previously acquired sessions can be reviewed in either Real-Time or Offline Playback.

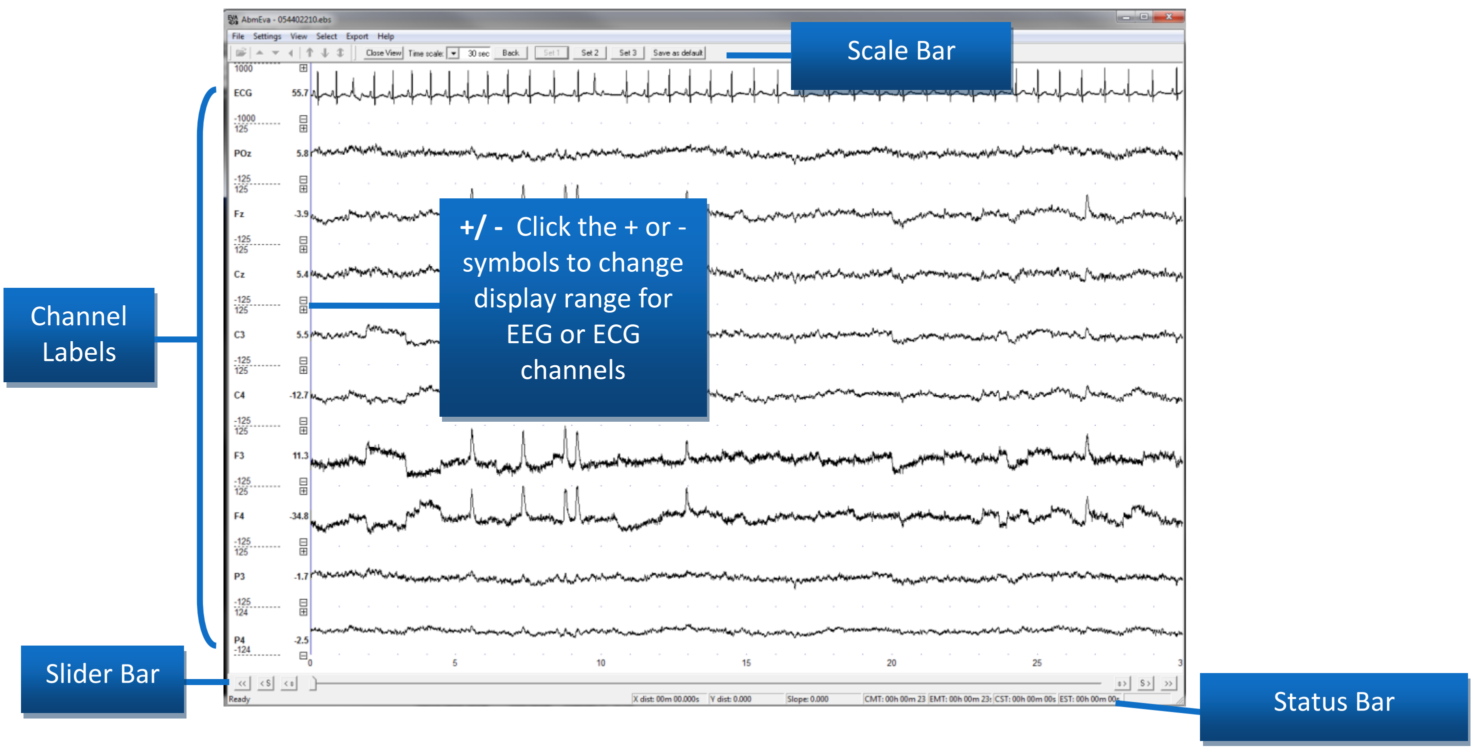
    a. Real-Time Playback – The file will be opened and presented in real-time, exactly the same as when the recording was initially acquired. Real-Time Playback mode is ideal for matching events of interest up to video recordings.

    b. Offline Playback – The file will be opened with the EVA offline analysis software. This allows the user to scroll forward and backward within the session to view signals and classifications. Offline mode is ideal for review of artifact problems. See **Section 9.2** for more details.

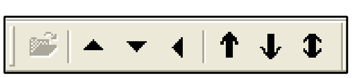
2. **Brain State:** During Playback it is optional to select whether the B-Alert and Workload Classifications are included. Artifact decontamination is also optional.
3. **Definition File:** If the subject has a baseline definition file created and the classification options are both checked, then the definition file must be selected. Note: the definition file selected must have the same 4-digit subject number as the session subject number.

9.2 Offline playback using EVA

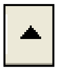
If 'Real- Time Playback' is left unchecked, the entire data file will be opened using the EVA software (ABM's offline data viewing platform). After clicking 'OK' with the 'Real-Time Playback' box *unchecked*, EVA will launch:



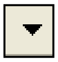
1. Toolbar:



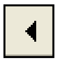
The toolbar controls the behavior of one channel when the channel is selected. To select a channel, hold the ctrl key and left-click on the channel. The selected channel will be highlighted in blue. Once selected, the buttons on the toolbar can be used:



Expand Selection: Expand the selected channels and hide all other channels from view.



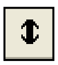
Remove Selection: Remove a selected channel from the view.



Undo Selection: Undo the last edit made.

Zoom Up: Change the scaling of the selected channel by zooming in.

Zoom Down: Change the scaling of the selected channel by zooming out.



Zoom Default: Change the scaling of the selected channel back to the default values.

2. Status Bar:

A number of time measures are available to identify periods of interest in a file. These time measures are based on the location of the mouse as you move it horizontally across the screen:

X dist: Not currently supported.

Y dist: Not currently supported.

Slope: Not currently supported.

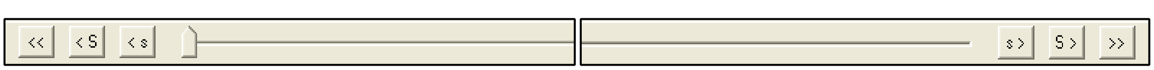
CMT (Clock Mouse Time): Allows the user to see a point in time based on the inserted clock time.

EMT (Elapsed Mouse Time): The Elapsed time since the start of the record.

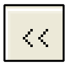
CST (Clock Start Time): The time at the start (left edge) of the screen. This value will not change as the cursor is moved across the screen.

EST (Elapsed Start Time): The record elapsed time at the start (left edge) of the screen. This value will not change as the cursor is moved across the screen.

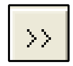
3. Slider Bar:



A number of methods are available to scroll through the file. The icons in the bottom left and right corners of the monitor shift the file:

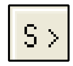


Backward to start of the file

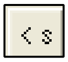


Forward to end of the file

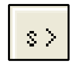
Backward one screen length



Forward one screen length



Backward one second



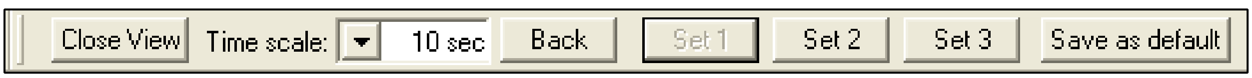
Forward one second

Pg Up: Backwards one screen length

Pg Dn: Forward one screen length


Left-click & drag the Pointer at the bottom of the screen to move anywhere in the file.

4. Scale Bar:



The options on the scale bar are used to modify the presentation of the signals as they appear with the EVA program in offline playback:

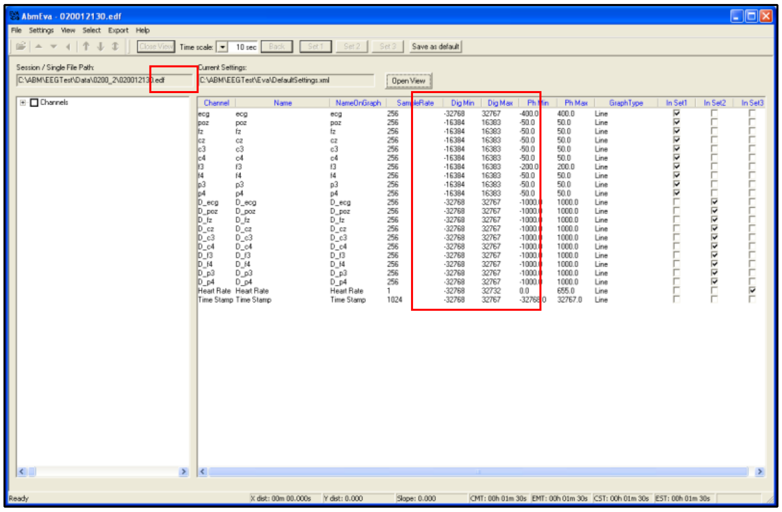
Time Scale: Adjusts the time scale for the signals presented on the screen.

Back: After the time scale is adjusted, the Back button will revert to the previous time scale.

Set 1, Set 2, Set 3: The default channel configurations recommended by ABM are presented when EVA opens. Set 1 is defaulted to show the raw EEG and ECG signals; users can select different channels to open in sets (similar to Tabs). Use the buttons to toggle between Sets 1, 2, and 3.

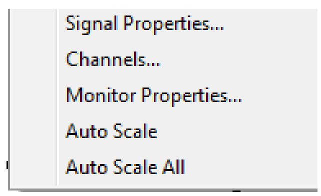
Save as Default: If any adjustments are made to the presentation of signals on Sets 1, 2, or 3 and it is desired to keep these settings as the default, use the Save as Default button. The next time EVA is opened, the new default settings will be presented.

Close View: Closes the default signal view and opens the channel configuration view. To return the default signal view, click the Open View button located on the channel configuration view. Use the 'InSet1', 'InSet2', and 'InSet3' check boxes to default channels to open in different sets in EVA.



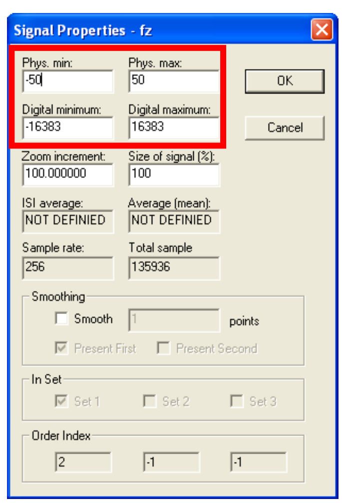
5. Right Click Menu:

Right click on the channels in the Main Window to bring up the Right-Click Menu:



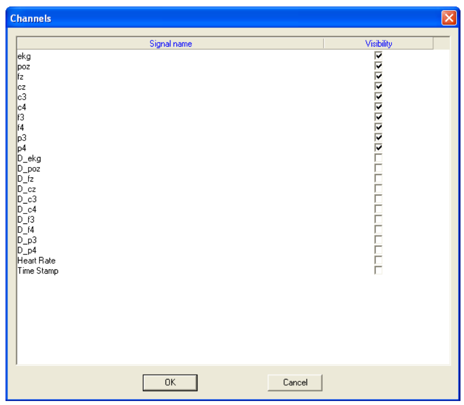
a. Signal properties:

- **Phys. Min/Phys. Max and Digital Minimum/ Digital Maximum:** adjusts the Y axis maximum and minimum ranges (in µV)



- **Zoom Increment:** Changes channel view by a zoom factor
- **Size of Signal (%):** Resizes channel range based on %
- **ISI average and Average (mean)**: Not supported
- **Sample Rate:** A fixed value and based on the samples/second in the .ebs
- **Total Sample:** Total # of data samples within a given .ebs
- **Smoothing:** Obsolete (not currently supported).
- **In Set:** Obsolete (not currently supported).

b. Channels: To adjust which channels are presented on the screen, right-click on the screen and select the channels option from the pop-up menu. Select or de-select the desired channels you wish to be visible in the current Set.



c. Monitor Properties: allows users to customize the display settings: fonts, colors, and axis properties.

d. AutoScale**:** Adjusts the Channel Y axis range based on Max/Min values for that channel across the entire file.

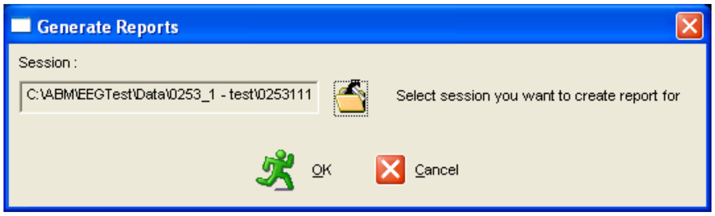
e. AutoScale All: Adjusts the Channel Y axis range based on Max/Min values for each channel in Set 1 across the entire file.

9.3 Generate Reports

To create data outputs with previously recorded data sessions, users can use the "Generate Reports" function. Consult **Appendix A: Data Outputs Guide** for additional information on the data output procedures and file descriptions.

1. Click on the "Generate Reports" icon.

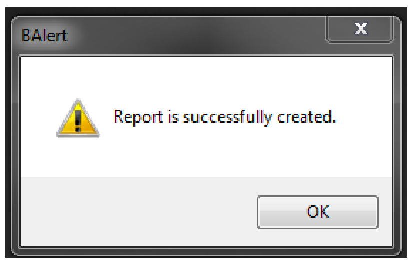
2. The Generate Reports window will appear:



3. Browse to and select the desired .ebs file. The .def file must be placed alongside the .ebs file to generate reports.

4. Click OK.

5. Wait for the Pop-Up window to appear, indicating report generation has completed:

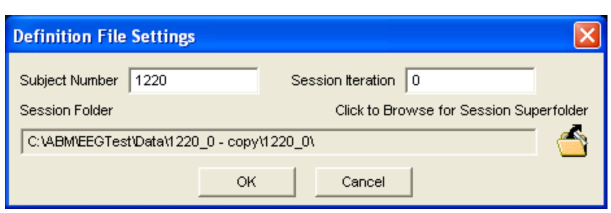


9.4 Create Definition File

After completing a B-Alert Baseline session, the definition (.def) file is automatically generated and saved to the subject folder. This .def file is used to generate the baseline report. If the .def file needs to be recreated, the "Create Definition File" icon can be used. **Note**: *All* baseline .ebs files must be located within the *same* folder, and have the same subject # for a .def file to generate properly. Follow the steps below to create a .def file.

1. Acquire necessary B-Alert Baseline Sessions (3-CVT, EO, EC).

2. Click the "Create Definition File" icon. The Definition File Settings window will open.:



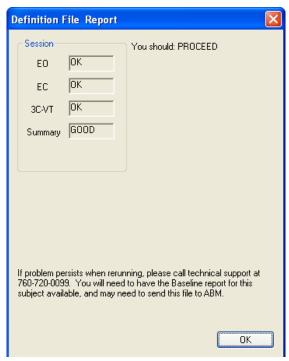
3. Enter the 4 digit subject number and session iteration number.

4. Browse to and select the session sub-folder that contains the 3 baseline .ebs files.

5. Click OK.

6. After several minutes the .def file creation will finish.

7. When the definition file creation is complete, the "Definition File Report" window will be presented. This window summarizes the results of .def file creation. If either the performance or EEG artifacts are outside of normal acceptable ranges, then you may see recommendations in this report to re-run B-Alert Baseline task(s). At least 5 minutes of each baseline task is required for .def file creation. Once created, the individualized .def file can be reused across sessions (for Brain State and/or Workload classification) for a given individual.



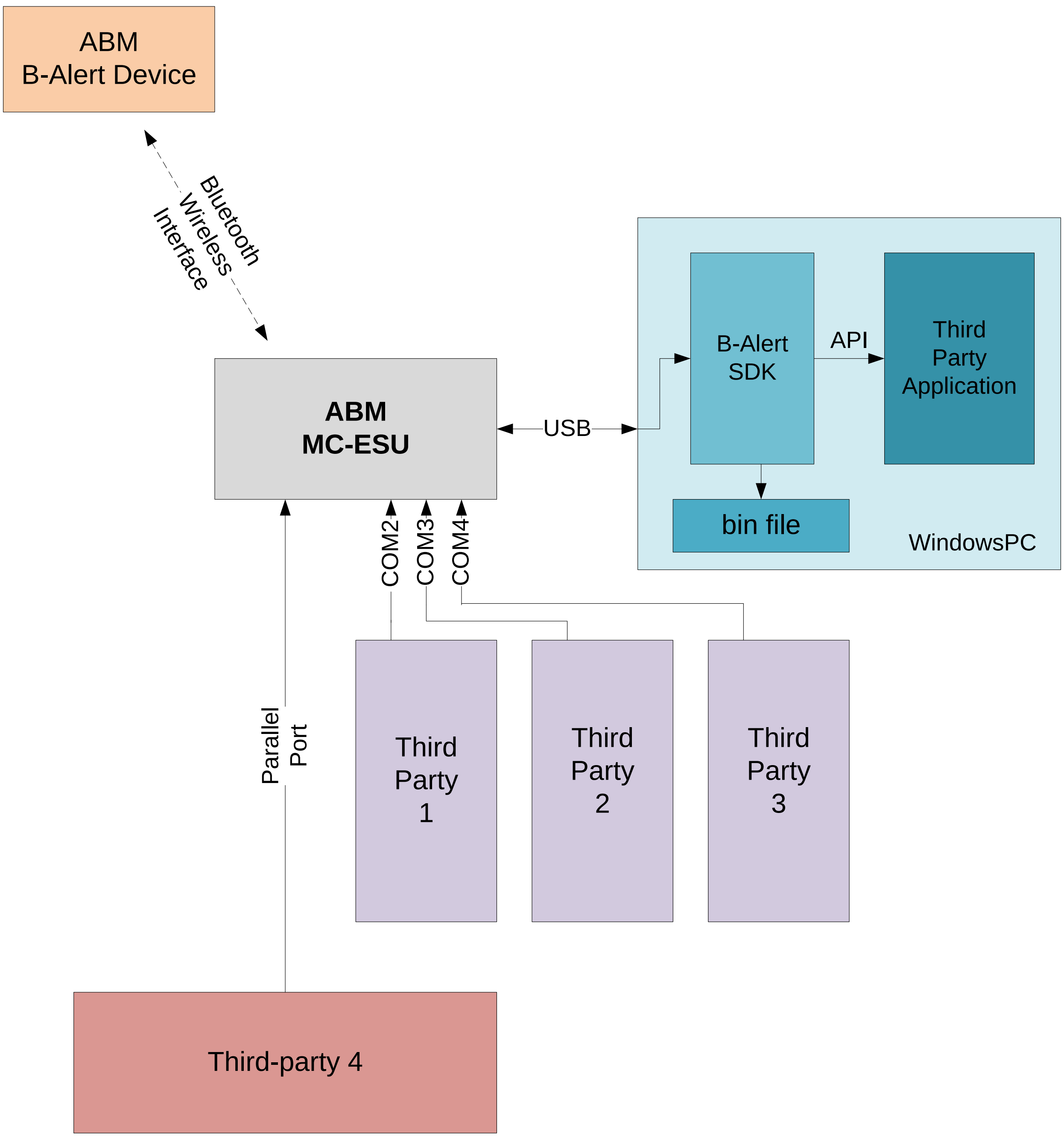
8. Check for the Definition File Report in the folder path to ensure the .def file was created.

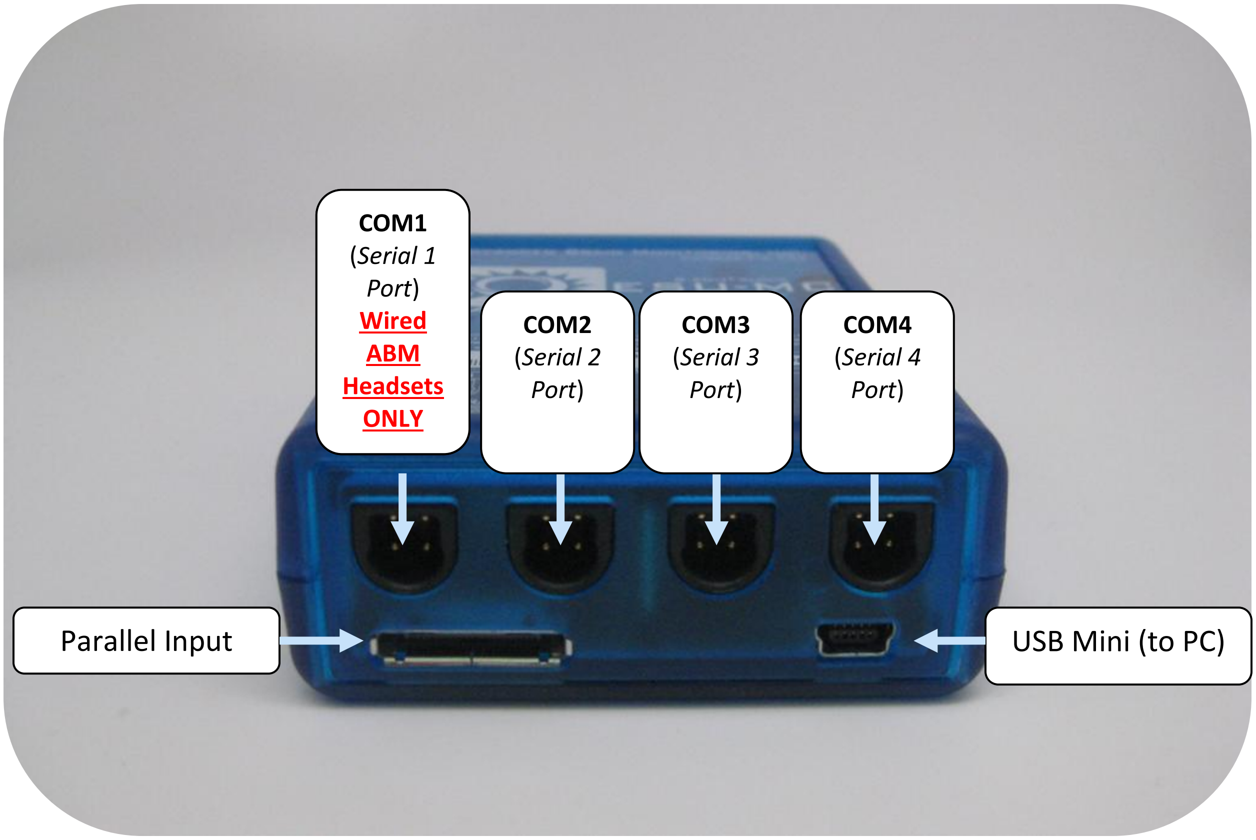
9. For additional consultation regarding .definition file validity, please contact ABM technical support.

After completing a B-Alert Baseline session or running the Create Definition file function, the Baseline Report is automatically generated and saved to the subject folder alongside the .def. The Baseline Report summarizes performance, classification data, and PSDs (along with heart rate, if available) across the three baseline tasks: the 3-Choice Vigilance Task (3-CVT; xxxxxx231.ebs), Eyes Open (EO; xxxxxx111.ebs), and Eyes Closed (EC; xxxxxx121.ebs). A Baseline Report will also be generated automatically during the definition file creation (see section below). For comparison purposes, population norms from a database of healthy, fully rested participants are included in the Baseline Report, for each of the three baseline tasks.

Chapter 10: External Sync Unit (ESU)

10.1 General ESU-MC information





The ABM Multi-Channel External Sync Unit (MC-ESU) can be used to timestamp both data from ABM devices and events from third party applications at millisecond level precision through a dedicated robust hardware timer. This addresses the limitations of time stamping using Windows timers, which introduces an average variable latency of ~30-50 msec in most circumstances due to the Windows scheduler. This variable latency can cause havoc in EEG signal analysis, especially in studies that rely on synchronization with external stimuli in order to extract event-related-synchronization/desynchronization as it reduces the Signal-To-Noise-Ratio (SNR) when averaging EEG samples to extract features such as evoked potentials. The MC-ESU thus eliminates Windows-related variable delay by time stamping data packets externally.

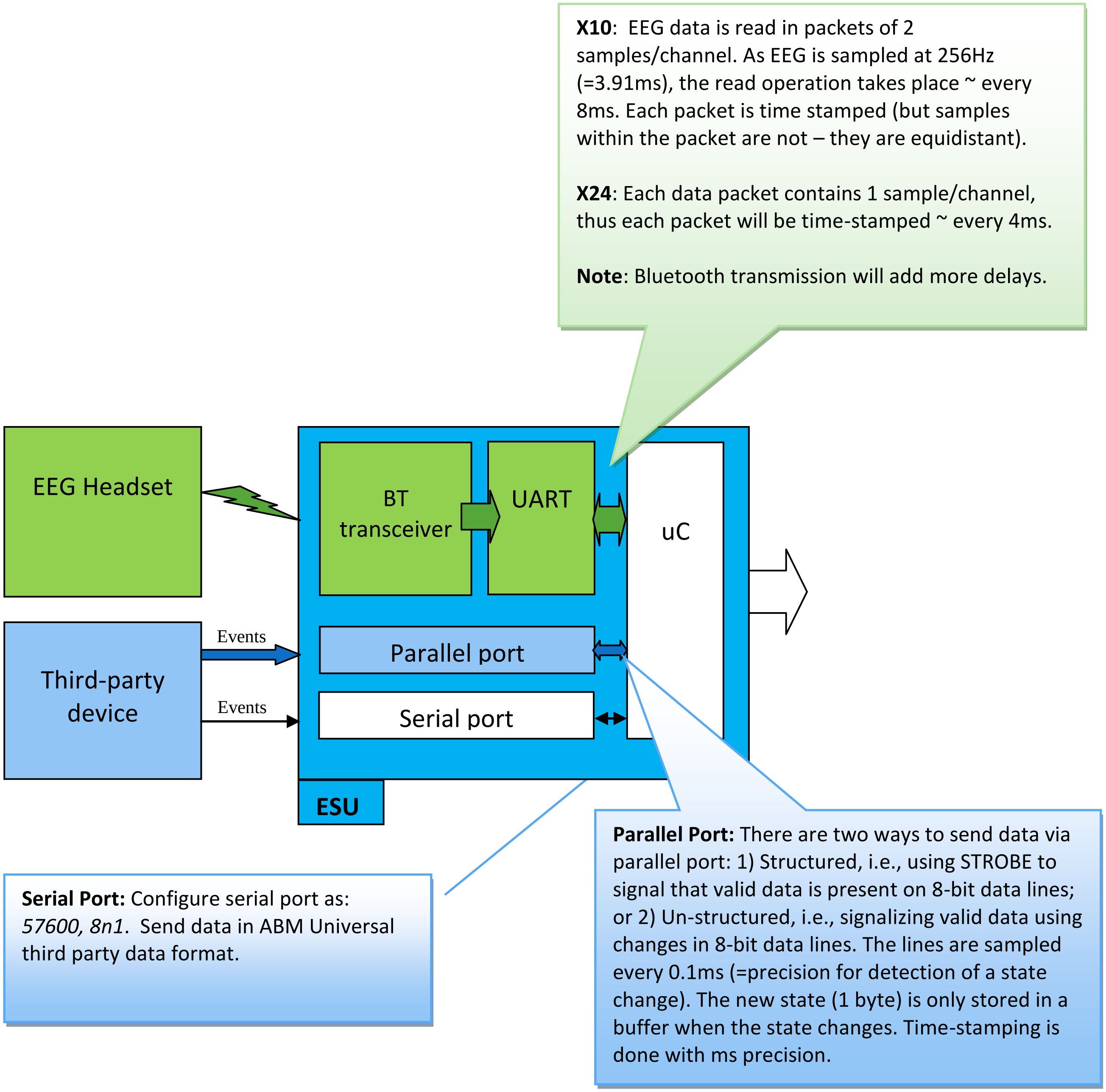
The MC-ESU also functions as a Bluetooth receiver for ABM devices, and it has the ability to decode ABM protocol and stream the data to the SDK via the USB port (i.e., the USB port registers a Virtual COM port in the PC). B-Alert X10 and X4 devices bundle two samples from each acquired signal into a single packet that gets time stamped every 8 msec, while the X24 sends only one sample and is time stamped every 4 msec. COM1 is reserved for ABM devices in wired configuration, while COM 2, 3, and 4 can be used to acquire third-party events via RS232 serial-port protocol. Applications can also send events via the parallel port, either with or without the STROBE signal. All third party events will be time stamped without delay in the MC-ESU, however, in the event of conflict, EEG packets will have priority over other data. Proprietary cables supplied with the MC-ESU (see Table 1) must be used to send data. All third-party applications must follow ABM protocol (specified in this chapter) while sending data to the MC-ESU. The SDK will unpack the third-party events and store them in a bin file or an

Events.EDF file along with ebs/edf data files for offline analysis. The third party events can also be acquired in real-time using SDK APIs.

Table 1: ESU Cables.

Cable Name	Photo
USB Cord (connect ESU to PC)	
Serial Port to ESU cable	
Parallel to ESU Cable	
4-pin to 4-pin serial (for **wired** headset data collection only)	

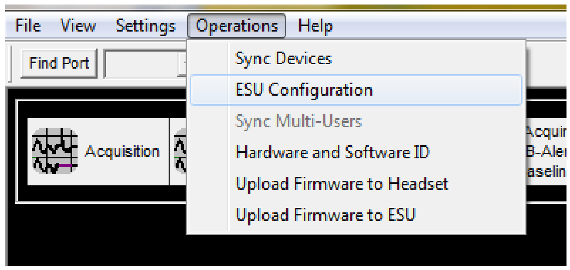
10.2 ESU Block Diagram



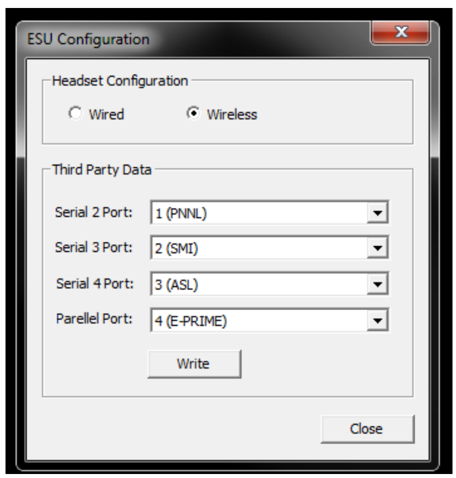
10.3 Configuring the ESU Settings

1. Plug in the ESU into USB port on a computer.

2. Open B-Alert Control GUI:



3. Under the 'Operations' Menu, select ESU Configuration. The ESU Configuration window will appear:



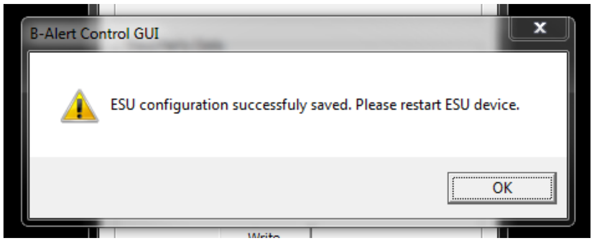
4. Use the drop down menus to configure ESU Third Party Data (3 Serial Ports and 1 Parallel Port) as desired. See **Third Party Data Format** (below) for the specifications for the different T-Party settings.

Warning:
Do NOT use the port labeled COM1 in the ESU for sending events from third-party interfaces. COM1 is dedicated to interface ABM headsets in wired configuration.

5. Use the 'Wired' and 'Wireless' radial buttons to configure the ESU for wired or wireless transmission modes (Headset will switch between wired/wireless transmission modes automatically).

6. Click the 'Write' Button to write settings changes to the ESU.

7. Wait. A pop-up window will appear to confirm the configuration was saved. Restart the ESU by unplugging and then re-plugging the ESU.



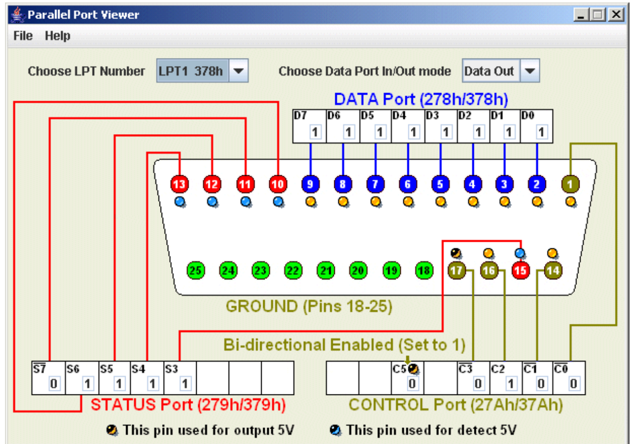
10.4 Third Party Protocols and Packet Structure

The MC-ESU supports multiple protocols for acquiring third party data. The specifications of the protocols are listed below:

Serial communication protocols				
Type	**Baud Rate (kb/s)**	**Data bits**	**Stop bit**	**Parity**
PNNL (recommended)	57600	8	1	None
SMI	9600	8	1	None
ASL	19200	8	1	None
AMP	Reserved	8	1	None

Parallel communication protocols		
Type	**STROBE (YES/NO)**	**Packet Structure (YES/NO)**
PNNL	Yes	Yes
ANITA	Yes	Yes
DAIMLER	No	No*
E-PRIME (recommended)	No	No*

*For protocols without a packet structure, the changes in the 8-bit parallel lines are time-stamped. Idle values (0) must be used in between valid data and the values must be held for at-least 100 usec for registration.



1. Sending data to the ESU

The third party applications must send packets according to the ABM Universal Protocol to the serial and parallel ports of the MC-ESU. The packet follows BIG ENDIAN format and has the following fields:

Flag 0x56, 0x5A (2 bytes)	Packet Length (2 bytes)	Packet Type (1 byte)	User Data (Number of bytes = Packet Length)	Check Sum (1 byte)

- Flag: fixed (0x56,0x5A)
- Packet Length: packet length is equal to the number of bytes in the User Data field
- Packet Type: depends on the type of protocol
    - PNNL (Serial = 1, Parallel = 2)
    - SMI (Serial = 3)
    - ASL (Parallel = 4)
    - AMP (Parallel = 8)
    - ANITA (Parallel = 6)
    - DAIMLER (Parallel = 7)
    - EPRIME (Parallel = 10)
- User Data:
- Checksum = 255 - Mod(SumOfAllBytes(Packet Length, PTY, DATA), 256)

Note: Sample programs for reference that mimic sending data through the serial port and the parallel port can be found within the installation folder.

2. Decoding data from the ESU

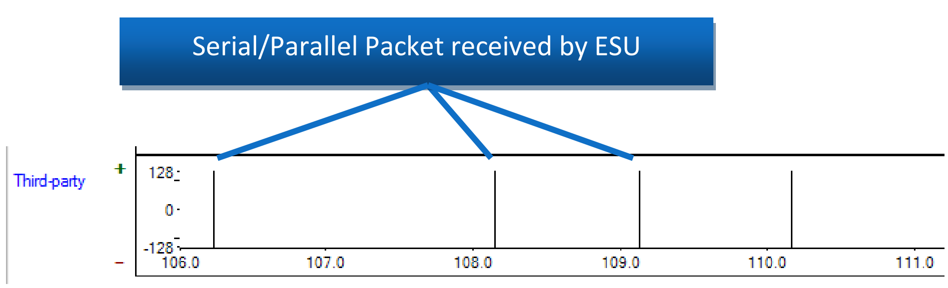
B-Alert software unpacks the data received from the MC-ESU and stores it in a bin file, or an events edf+ file. The events packet has the following structure for each event:

Flag 0x56, 0x56 (2 bytes)	Message Counter (1 byte)	ESU Timestamp (4 bytes)	Packet Length (2 bytes)	Packet Type (1 byte)	User Data (Number of bytes = Packet Length)	Check Sum (1 byte)

- Flag: fixed (0x56,0x56)
- Message Counter: (reserved)
- ESU Timestamp: 4-bytes ESU timestamp in BIG ENDIAN format (the timestamp can be reconstructed using multiples of 2 (for example, timestamp in millisec = BYTE1*2^24 + BYTE2*2^16 + BYTE3*2^8 + BYTE4*2^0)
- Packet Length: equal to the number of bytes in User Data field
- Packet Type: protocol used
- User Data
- Checksum: Mod(SumOfAllBytes(Packet Length, PTY, DATA), 256)

10.5 Visualizing Third Party data during Data acquisition

To monitor the stream of incoming data to the ESU (Serial and Parallel), users can select the additional channels for display from the Channel Map Window (see **Chapter 8**) After selecting the 'Third Party' option, a 'Third-Party' channel will appear at the bottom of the raw signals window. All incoming packets to the ESU (if formatted in proper structure) will appear as strobes in this line:



Note:
These strobes will only reflect the time when the packet was received by the ESU, and will not contain any information about the content of the packet.

Appendix A: Data Outputs Guide

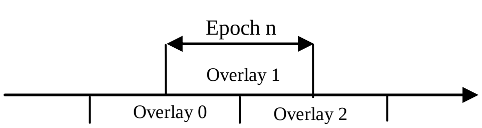
A.1 Overview

ABM's B-Alert software allows users to utilize some of ABM's Artifact Identification, EEG-Classification, PSD, and ECG algorithms if desired. These data outputs are either created in real time (See Real Time Data Outputs) or offline (see **Appendix A.8**: Create .def file Outputs and **Appendix A.9**: Generate Reports Outputs). Below is an overview of some of the methods and techniques used by ABM to compute its various measures.

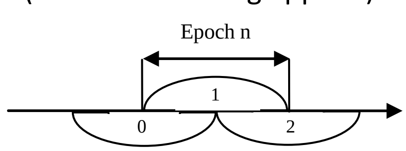
1. **Computing Power Spectral Densities:** Power spectral density (PSD) is computed by performing Fast Fourier Transform (FFT) on a segment of data that is of interest, and calculating the amplitudes of the sinusoidal components for designated frequency bins. Input variables to this transformation are an EEG segment for which PSD is to be computed, and its length; output variables include PSD amplitudes. Frequency domain variables are based on the power spectral density derived after application of a 50% overlapping window, and a FFT with ('_raw') and without ('_class') application of a Kaiser window. The B-Alert software provides two sets of PSD values (Ref_Raw and Ref_Class) from 1 to 40 Hz for each EEG channel that are logged to obtain a Gaussian distribution. Selected 1-Hz bins are averaged, then logged to create conventional EEG bands (e.g., theta = 3 – 7 Hz, alpha = 8 – 12 Hz, etc.). 'Diff_' files contain data for Differential EEG channels used for ABM's Classification measures (FzPOz, CzPO, FzC3, C3C4, F3Cz). 'Ref_' files contain PSD values for 9 referential EEG channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4).

   Both sets of PSD output files apply a 50% overlapping window which averages the PSD across three x one-second overlays to smooth the data. The illustration below shows that overlays 0, 1, and 2 are averaged (each overlay containing 256 data points with 128 data points being shared for each overlay) to provide the PSD values for epoch n:

   50% Overlap – Ref_Raw, Diff_Raw



   50% Overlap – Ref_Class, Diff_Class
   (Kaiser windowing applied)

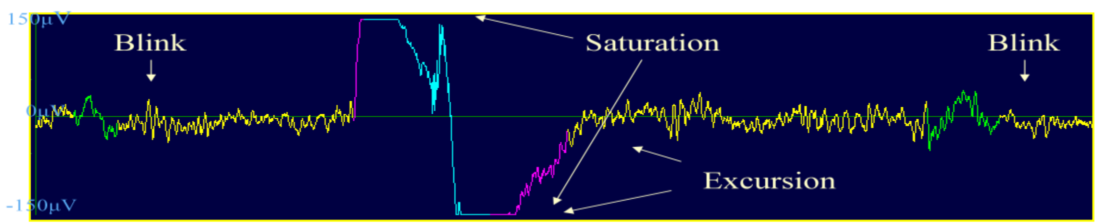


   For the 'Ref_Class.csv' and 'Diff_Class.csv' PSD calculation, a Kaiser window is applied to each overlay in order to accentuate the contribution of power from the signal in the middle third of the overlay, and minimize the impact of signal near each edge of the overlay.

Windowing reduces the likelihood of extreme PSD values resulting from edge-effects when an EEG wave shape does not begin or end at the exact edge of an overlay. No Kaiser windowing is used for Ref_Raw and Diff_Raw analysis. ABM recommends using the _Raw data for users wishing to use PSD-based computations using this PSD overlaying procedure.

2. **Decontaminating Signals**: Prior to computing the 1-Hz PSD bins, the raw signals are processed to eliminate known artifacts. Spikes, excursions and amplifier saturations, which occur when ambulatory EEG is acquired, can impact both low and high frequencies. EMG will contaminate the beta and sigma frequency ranges. Eye blinks occur in the same frequency range as theta activity.

Before Decontamination:



After Decontamination:

- Excursions and amplifier saturation – contaminated periods are replaced with zero values, starting and ending at zero crossing before and after each event.

- Spikes caused by artifact are identified and signal value is interpolated.

- Invalid Epochs – If more than 128 zero values are inserted for an overlay, the overlay is excluded from the epoch average; if 2 of the 3 overlays are rejected, the epoch is classified 'invalid' (-99999 inserted for PSD value) and should be excluded from analysis.

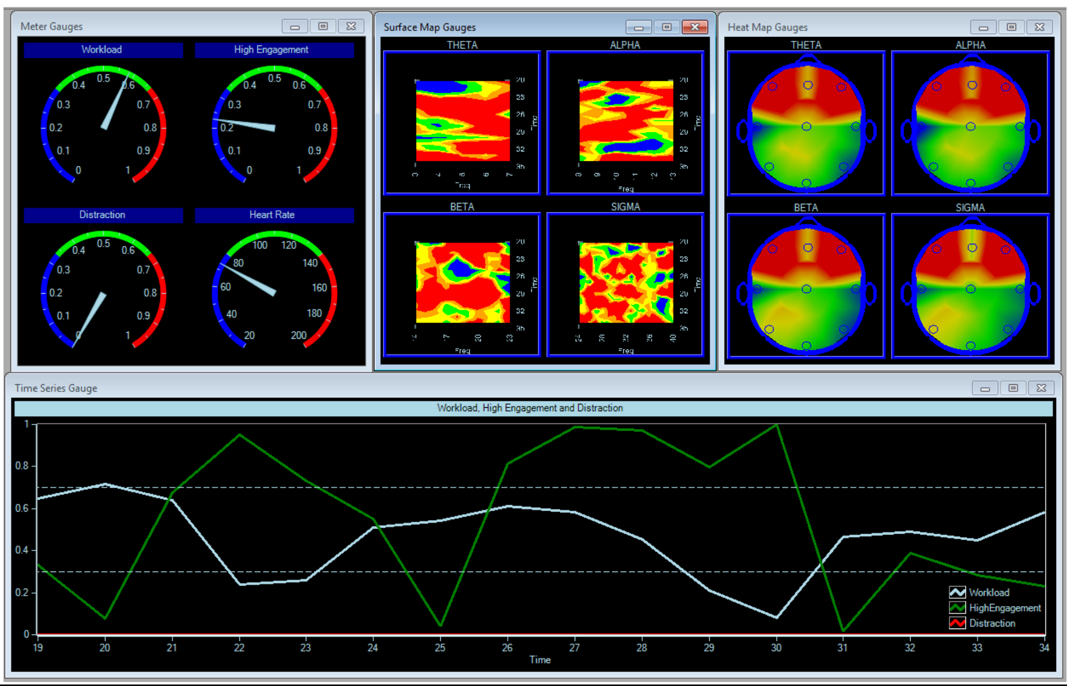
- EMG – a combination of High Frequency EMG (based off 70 - 128 Hz bins for each overlay) and Low Frequency EMG (based off 35 - 40 Hz) is used to identify periods with excessive EMG. If only one overlay has EMG, the PSD for the epoch is based on the average of the remaining two overlays. If excessive EMG is detected in two overlays, the second is classified as 'EMG' and should be excluded from analysis.

- Eye Blinks – wavelet transforms deconstruct the signal and a regression equation is used to identify the EEG regions contaminated with eye blinks. Representative EEG preceding the eye blink is inserted in the contaminated region.

The artifacts are colored as follows:

Artifact Type	Color
EMG	Orange
Eye-blinks	Blue
Saturation	Light Blue
Excursion	Dark Green
Spike	Dark Brown

3. Classifying Cognitive States (B-Alert And Workload Models):



B-Alert Wireless EEG bio-metrics are normalized to an individual subject using 5-7 min of baseline data from three distinct tasks (3CVT, EO, and EC), with the sleep onset class predicted from the baseline PSD values, for a total of 15-17 min of data across tasks. Based on this identification data, a probability-of-fit is then generated for each of the four classes for each epoch with the sum of the probabilities across the four classes equaling 1.0 (e.g., 0.45 high engagement, 0.30 low engagement, 0.20 distraction and 0.05 sleep onset). Cognitive State for a given second represents the class with the greatest probability using numeric labels (.1 = sleep onset, .3 = distraction, .6 = low engagement, and .9 = high engagement). B-Alert cognitive state metrics are derived for each one-second epoch using 1 Hz PSDs (from the bins from differential sites FzPOz, CzPO, FzC3, C3C4, F3Cz) in a four-class quadratic discriminant function analysis (DFA) that is fitted to the individual's unique EEG patterns. The table below identifies and briefly describes each baseline task, and associates the task with the B-Alert classification.

Baseline task	Action	B-Alert Class probabilities
3-choice vigilance task (~7-min; optional 20-min)	Discriminate between primary vs. secondary or tertiary stimulus every 1.5 to 3 seconds	High Engagement
Eyes open (5-min)	Respond to visual probe every 2 seconds	Low Engagement
Eyes closed (5-min)	Respond to audio tone every 2 seconds	Distraction
None	Derived by regression from other 3 tasks	Sleep Onset

Important Note: ***Failure to collect these 3 specific baseline tasks will result in an inability to utilize the B-Alert Cognitive State Classifications.***

The B-Alert probabilities for each individual should be interpreted in a relative, rather than absolute, manner. Three standardized baseline tasks normalize the cognitive state metrics to each individual. High population variability for EEG activity requires individualized model fitting, which is done for each 1-Hz bin (from 1-40Hz), and is not fit to classic summed bandwidths/rhythms (i.e. theta, alpha, beta, etc.) to optimize classification measures.

Two individuals will generate somewhat different probabilities for the same task due to a) their innate capability, and b) their state during acquisition of baseline data. If a participant is mentally balancing their checkbook during the eyes closed task, for example, they will not generate as much alpha activity as they would in a relaxed state. This may increase the occurrence of Distraction probabilities when applied to a different task in which they do mentally relax. Participants are more aroused the first time they complete a baseline session due to the novelty, so it is preferable to reuse the individual's DFA to classify new data/sessions rather than re-run the identification tasks repeatedly. Participants should avoid consumption of caffeine or nicotine immediately prior to baseline/identification acquisition; and the session should occur in the morning (8am-10am) after a full night of sleep to collect an optimal session.

The B-Alert Workload metric is a generalized model (i.e., it is not individually fit), thus it should also be interpreted in a relative manner. For the linear 2-class workload DFA, probabilities closer to 1 reflect higher workload. EEG workload is correlated with increased working memory load and difficulty level in mental arithmetic and other complex problem solving tasks. ABM has 2 workload models -- one model was built on a Forward digit span (FBDS) task (recommended to use, as it fits for ~85% of population) and the other built on a backward digit span (BDS) task (fits ~15% of population). ABM's data outputs also contain the mean probability between the FBDS and BDS model.

Z-scoring is a useful transformation to convert the relative B-Alert metrics into values that can be compared across participants, or for a repeated-measures within-subject experimental design.

4. **Output files**: EEG and other raw data is stored in both EBS and EDF files. The EDF file is compatible with most of the third-party EDF viewers. The csv output files generated with the B-Alert software share common formatting features. For example, all file names begin with the nine digit subject/session number (XXXXXXXXX), followed by the label which describes the data. For generated files, one row of data is provided per second of recording time. The first column lists the subject/session number, the second column the elapsed time (since the start of recording) in hour:minute:second:millisecond (HH:MM:SS:MS), and the third column the system clock time associated with the start of the primary (middle) overlay for the epoch. Output files use a comma separated value (CSV) format for easy import into statistical/analytical software applications.

Real-Time Data Outputs Overview Table

Real-Time Output file name	**Description**
Data file	
Xxxxxxxxx.ebs	Proprietary Extensible bio-signal file format. Stores raw data with identical sampling such as EEG and EKG.
Xxxxxxxxx.edf	European data format containing raw data with variable sampling such as EEG, EKG, Decontaminated EEG, Accelerometer data, Marker etc. The EDF file is compatible with most third party viewers. Some channels in EDF file are selectable (see **Chapter 8**).
XxxxxxxxxDecon.ebs	Decontaminated EEG signal.
Xxxxxxxxx_impedance_results.csv	Lists the values obtained for each channel each time impedance was measured.
Automatically Generated during Acquisition – for all EEG Channels	
Xxxxxxxxx_Ref_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (no edge-effect window)
Xxxxxxxxx_Ref_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (with Kaiser window)
Automatically Generated during Acquisition – Derived Signals	
Xxxxxxxxx_HR_beat.csv	Presentation of heart rate based on beat-to-beat interval
Xxxxxxxxx_HR_epoch.csv	Beat-to-beat heart rate interpolated to sec-by sec value
Optionally Generated with B-alert Cognitive State Classifications	
Xxxxxxxxx_Classification.csv	Probabilities for sleep, distraction, low and high engagement, cognitive state from DFA with greatest probability, probability of high workload based on forward and backward digit span

	(FBDS), backward digit span (BDS), and average of FBDS and BDS.
Xxxxxxxxx_Diff_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for differential channels: FzPO,CzPO,FzC3,C3C4, and F3Cz (no edge-effect window).
Xxxxxxxxx_Diff_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for 5 differential channels FzPOz, CzPO, FzC3, C3C4, F3Cz (with Kaiser window).
Xxxxxxxxx_Zscore.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for B-Alert cognitive states (sleep onset, distraction, low and high engagement, three workload measures).
Xxxxxxxxx_Zscore_psd.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for PSD for all channels requested in initialization process.
Other files	
Xxxxxxxxx_Actigraphy.csv	Contains raw tilt values from accelerometer and derived movement vales/scales.
Xxxxxxxxx_Artifact.csv	Contains detected artifacts and their start/end markers.
Xxxxxxxxx_ArtifactInfo.csv	Contains epoch-by-epoch details of artifacts detected in each channel such as number of datapoints affected, number of datapoints with inserted zero values, etc.
Xxxxxxxxx_thirdparty.bin	Stores third-party packets sent to the ESU (only for ESU).
Xxxxxxxxx_optical.bin	Stores IRED data from the headset (only for X4).
Xxxxxxxxx_accelerometer.csv	Stores raw accelerometer data in bin format.

Offline Data Outputs Overview Table

Real-Time Output file Extensions	**Description**
EEG Classification Reports	
.eec	Lists classification probabilities, summary of artifacts, HR and HRV measures.
_datasummary.csv	Summary EEG classification information averaged across an entire session.
Heart Rate Reports	
HR.csv	Second by Second (Epoch-by-epoch) heart rate (HR) data and time domain heart rate variability (HRV).
Summary_HR.csv	Summary HR and HRV data over the entire session.
HRV.csv	HRV data averaged over each 5 min window in the session (frequency domain computation).
PSD_HRV.csv	Contains the ECG PSDs for each 5 min interval from .01 - .40Hz.

Power Spectral Density (PSD) Reports **_Ref: Referential EEG channels (**all channels in X10, X24**)** **_Class: Differential EEG channels** (FzPO, CzPO, FzC3, C3C4, F3Cz in X10,X24; FzPO, CzPO in X4)	
.psd	Second to second PSDs are computed for each channel (relative and absolute PSD) for 3-40Hz bin, and PSD bandwidths Theta (Fast, Slow, and Total), Alpha (Fast, Slow, and Total), Beta, Gamma, Sigma.
.sbw	Summary Bandwidth information for Theta, Alpha, Beta, Gamma, and Sigma across the entire session: Theta (Fast, Slow, and Total), Alpha (Fast, Slow, and Total), Beta, Gamma, Sigma.
.EBW	Second to Second PSD Bandwidth data for Theta (Fast, Slow, and Total), Alpha (Fast, Slow, and Total), Beta, Gamma, Sigma.
Obsolete Output Files	
.wf10	**These File types are Obsolete and no longer supported.**
.df10	
.fpc	

Note:
The files created during acquisition depend on the selection in "Configure Data Storage" setting (see **Chapter 8**). It also depends on the type of processing selected (Artifact Decontamination), Brain State Classifications (B-Alert, Workload) and type of the device used (X4, X10, X24).

A.2 Classification (B-Alert and Workload) Output

1. _Classification.csv

Classification.csv shows the second by second (epoch by epoch) data outputs for ABM's two EEG models: (1) 4-Class B-Alert model of drowsiness: (Sleep Onset, Distraction, Low Engagement, High Engagement); and 2-Class model of Workload (High Workload). These outputs will ONLY be generated if the user has checked either of the 'Brain State' check boxes (B-Alert Classification and/or Workload Classification), and selected the appropriate .def file prior to initializing a data Acquisition.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time(hh:mm:ss:ms)
D	ProbSleepOnset	Sleep Onset classification probability (0-1)
E	ProbDistraction	Distraction classification Probability (0-1)
F	ProbLowEng	Low Engagement classification probability (0-1)
G	ProbHighEng	High Engagement classification probability (0-1)

H	CogState	The highest Probability in columns D, E, F, G will determine what the epoch is classified. Classifications are: 0.1: Sleep onset, 0.3: Distraction, 0.6: Low Engagement, 0.9: High Engagement. Seconds with excessive artifact where classification data could not be computed are identified with 0.05, 1, and/or 2.
I	ProbFBDSWorkload	Raw Workload probability (FBDS model), where higher probability reflects higher WL (FBDS is the best model for 85% of population).
J	ProbBDSWorkload	Alternate WL model (BDS model): Not recommended for use, higher probability reflects higher WL (Best WL model for other 15% of population).
K	ProbAveWorkload	Average Workload between 2 models (in Columns I and J).

A.3 Power Spectral Densities Outputs

_Diff_Class.csv
_Diff_Raw.csv
_Ref_Class.csv
_Ref_Raw.csv

Power spectral density (PSD) is computed by performing Fast Fourier Transform (FFT) on a segment of data that is of interest, and calculating the amplitudes of the sinusoidal components for designated frequency bins. Input variables to this transformation are an EEG segment for which PSD is to be computed, and its length; output variables include PSD amplitudes. Frequency domain variables are based on the power spectral density derived after application of a 50% overlapping window, and a FFT with (_raw) and without (_class) application of a Kaiser window. Refer to Outputs Overview above for additional information regarding the PSD analysis procedures.

1. Diff_Class.csv

PSDs (1-40Hz) for the *differential channels (*FzPOz, CzPO, FzC3, C3C4, F3Cz) are computed for generating ABM's classifications for each second of a given .ebs file. PSDs in this file are computed for each second of a given session **with** the Kaiser Windowing procedure described above. ***Relative*** power values are derived by subtracting the logged power of the individual Hz bin from the summed logged power for the EEG band (1 – 40 Hz) for that channel.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)

B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	fzpoz_1	PSD power at channel FzPoz (with Kaiser windowing) for the 1 Hz bin
E	fzpoz_2	PSD power at channel FzPoz (with Kaiser windowing) for the 2 Hz bin
F - AQ	fzpoz_3-40	PSD power at channel FzPoz (with Kaiser windowing) for the 3-40 Hz bins
AR	fzpoz_rel1	*Relative* PSD power at channel FzPoz (with Kaiser windowing) for 1 Hz Bin
AS - CE	fzpoz_rel2-rel40	*Relative* PSD power at channel FzPoz (with Kaiser windowing) for 2-40 Hz Bin
CF	fzpoz_Delta_1_2	PSD for Delta Bandwidth at channel FzPoz (not relative PSD) summed from Hz bins 1-2
CG	fzpoz_ThetaSlow_3_5	PSD for Theta-Slow Bandwidth (not relative PSD) summed from Hz bins 3-5
CH	fzpoz_ThetaFast_5_7	PSD for Theta-Fast Bandwidth (not relative PSD) summed from Hz bins 5-7
CI	fzpoz_ThetaTotal_3_7	PSD for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7
CJ	fzpoz_AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth (not relative PSD) summed from Hz bins 8-10
CK	fzpoz_AlphaFast_10_12	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 10-12
CL	fzpoz_AlphaTotal_8_12	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 8-12
CM	fzpoz_Beta_13_29	PSD for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29
CN	fzpoz_Sigma_13_29	PSD for Sigma Bandwidth (not relative PSD) summed from Hz bins 13-29
CO	czpoz_1	PSD power at channel CzPOz (with Kaiser windowing) for the 1 Hz bin
CP - QF		PSD/Relative PSD information for all differential channels (CzPOz, FzC3, C3C4, F3Cz uses the same naming convention as FzPOz, described above)
QG	ThetaOverall_3_7	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7
QH	AlphaOverall_8_12	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-12
QI	BetaOverall_13_29	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29
QJ	SigmaOverall_30_40	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Beta Bandwidth (not relative PSD) summed

		from Hz bins 30-40

2. Diff_Raw.csv

PSDs (1-40Hz) for the *differential channels (*FzPOz, CzPO, FzC3, C3C4, F3Cz) are computed for generating ABM's classifications for each second of a given .ebs file. PSDs in this file are computed for each second of a given session *without* the Kaiser Windowing procedure. *Relative* power values are derived by subtracting the logged power of the individual Hz bin from the summed logged power for the EEG band (1-40Hz) for that channel.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	fzpoz_1	PSD power at channel FzPoz (without Kaiser windowing) for the 1 Hz bin
E	fzpoz_2	PSD power at channel FzPoz (without Kaiser windowing) for the 2 Hz bin
F - AQ	fzpoz_3-40	PSD power at channel FzPoz (without Kaiser windowing) for the 3-40 Hz bins
AR	fzpoz_rel1	*Relative* PSD power at channel FzPoz (without Kaiser windowing) for 1 Hz Bin
AS - CE	fzpoz_rel2-rel40	*Relative* PSD power at channel FzPoz (without Kaiser windowing) for 2-40 Hz Bin
CF	fzpoz_Delta_1_2	PSD for Delta Bandwidth at channel FzPoz (not relative PSD) summed from Hz bins 1-2 (without Kaiser windowing)
CG	fzpoz_ThetaSlow_3_5	PSD for Theta-Slow Bandwidth (not relative PSD) summed from Hz bins 3-5 (without Kaiser windowing)
CH	fzpoz_ThetaFast_5_7	PSD for Theta-Fast Bandwidth (not relative PSD) summed from Hz bins 5-7 (without Kaiser windowing)
CI	fzpoz_ThetaTotal_3_7	PSD for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7(without Kaiser windowing)
CJ	fzpoz_AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth (not relative PSD) summed from Hz bins 8-10 (without Kaiser windowing)
CK	fzpoz_AlphaFast_10_12	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 10-12 (without Kaiser windowing)
CL	fzpoz_AlphaTotal_8_12	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 8-12(without Kaiser windowing)
CM	fzpoz_Beta_13_29	PSD for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)
CN	fzpoz_Sigma_13_29	PSD for Sigma Bandwidth (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)
CO	czpoz_1	PSD power at channel CzPOz (with Kaiser windowing) for the 1 Hz

		bin (without Kaiser windowing)
CP - QF		PSD/Relative PSD information for all differential channels (CzPOz, FzC3, C3C4, F3Cz uses the same naming convention as FzPOz (described above)
QG	ThetaOverall_3_7	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7 (without Kaiser windowing)
QH	AlphaOverall_8_12	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-12 (without Kaiser windowing)
QI	BetaOverall_13_29	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)
QJ	SigmaOverall_30_40	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Beta Bandwidth (not relative PSD) summed from Hz bins 30-40 (without Kaiser windowing)

3. Ref_Class.csv

PSDs (1-40Hz) for the *referential channels* are computed for generating ABM's classifications for each second of a given .ebs file. PSDs in this file are computed for each second of a given session *with* the Kaiser Windowing procedure described above. *Relative* power values (_rel) are derived by subtracting the logged power of the individual Hz bin from the summed logged power for the EEG band (1-40Hz) for that channel.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	POz_1	PSD power at channel POz (with Kaiser windowing) for the 1 Hz bin
E	POz_2	PSD power at channel POz (with Kaiser windowing) for the 2 Hz bin
F - AQ	POz_3-40	PSD power at channel POz (with Kaiser windowing) for the 3-40 Hz bins
AR	POz_rel1	*Relative* PSD power at channel POz (with Kaiser windowing) for 1 Hz Bin
AS - CE	POz_rel2-rel40	*Relative* PSD power at channel POz (with Kaiser windowing) for 2-40 Hz Bin
CF	POz_Delta_1_2	PSD for Delta Bandwidth at channel POz (not relative PSD) summed from Hz bins 1-2 (with Kaiser windowing)
CG	POz _ThetaSlow_3_5	PSD for Theta-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-5 (with Kaiser windowing)

CH	POz _ThetaFast_5_7	PSD for Theta-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 5-7 (with Kaiser windowing)
CI	POz _ThetaTotal_3_7	PSD for Theta-Total Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-7 (with Kaiser windowing)
CJ	POz _AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-10 (with Kaiser windowing)
CK	POz _AlphaFast_10_12	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 10-12 (with Kaiser windowing)
CL	POz _AlphaTotal_8_12	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-12 (with Kaiser windowing)
CM	POz _Beta_13_29	PSD for Beta Bandwidth at channel POz (not relative PSD) summed from Hz bins 13-29 (with Kaiser windowing)
CN	POz _Sigma_13_29	PSD for Sigma Bandwidth at channel POz (not relative PSD) summed from Hz bins 13-29 (with Kaiser windowing)
CO	Fz_1	PSD power at channel Fz (with Kaiser windowing) for the 1 Hz bin (with Kaiser windowing)
CP - ADX		PSD information for all referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4); uses the same naming convention and analysis as Fz (described above-- all with Kaiser windowing)
ADY	ThetaOverall_3_7	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7 (with Kaiser windowing)
ADZ	AlphaOverall_8_12	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-12 (with Kaiser windowing)
AEA	BetaOverall_13_29	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29 (with Kaiser windowing)
AEB	SigmaOverall_30_40	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Sigma Bandwidth (not relative PSD) summed from Hz bins 30-40 (with Kaiser windowing)

4. Ref_Raw.csv

PSDs (1-40Hz) for the *referential channels* are computed for generating ABM's classifications for each second of a given .ebs file. PSDs in this file are computed for each second of a given session *without* the Kaiser windowing procedure. *Relative* power values (_rel) are derived by subtracting the logged power of the individual Hz bin from the summed logged power for the EEG band (1–40 Hz) for that channel.

Column	**Column Name**	**Description**
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured)

		(hh:mm:ss:ms)
D	POz_1	PSD power at channel POz (without Kaiser windowing) for the 1 Hz bin
E	POz_2	PSD power at channel POz (without Kaiser windowing) for the 2 Hz bin
F - AQ	POz_3-40	PSD power at channel POz (without Kaiser windowing) for the 3-40 Hz bins
AR	POz_rel1	*Relative* PSD power at channel POz (without Kaiser windowing) for 1 Hz Bin
AS - CE	POz_rel2-rel40	*Relative* PSD power at channel POz (with Kaiser windowing) for 2-40 Hz Bin
CF	POz_Delta_1_2	PSD for Delta Bandwidth at channel POz (not relative PSD) summed from Hz bins 1-2 (without Kaiser windowing)
CG	POz _ThetaSlow_3_5	PSD for Theta-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-5 (without Kaiser windowing)
CH	POz _ThetaFast_5_7	PSD for Theta-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 5-7 (without Kaiser windowing)
CI	POz _ThetaTotal_3_7	PSD for Theta-Total Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-7(without Kaiser windowing)
CJ	POz _AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-10 (without Kaiser windowing)
CK	POz _AlphaFast_10_12	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 10-12 (without Kaiser windowing)
CL	POz _AlphaTotal_8_12	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-12 (without Kaiser windowing)
CM	POz _Beta_13_29	PSD for Beta Bandwidth at channel POz (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)
CN	POz _Sigma_13_29	PSD for Sigma Bandwidth at channel POz (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)
CO	Fz_1	PSD power at channel Fz (without Kaiser windowing) for the 1 Hz bin
CP - ADX		PSD/Relative PSD information for all referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) uses same naming convention and analysis as Fz (described above -- all without Kaiser windowing)
ADY	ThetaOverall_3_7	Mean PSD across ALL referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7 (without Kaiser windowing)
ADZ	AlphaOverall_8_12	Mean PSD across ALL referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-12 (without Kaiser windowing)
AEA	BetaOverall_13_29	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)
AEB	SigmaOverall_30_40	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Sigma Bandwidth (not relative PSD) summed from Hz bins 30-40 (without Kaiser windowing)

Note:
Ref_xxx.csv files will not be generated for B-Alert X4, as it does not have referential channels.

A.4 Heart Rate Outputs

_HR_beat.csv
_HR_epoch.csv

Signal processing performs 5 operations on the raw EKG (ECG) signal, the output being a signal with QRS complexes enhanced, and other components attenuated. The r to r interval is calculated to determine each heart rate. Heart rate variability will be determined based on detected heart rate values. ABM's Heart Rate (HR) algorithm computes beat to beat (_HR_beat.csv) and second by second (_HR_Epoch.csv).

1. _HR_beat.csv

This file contains the beat to beat heart rate data based on ABM's Heart Rate algorithm.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	Beat Quality	1 or 0 value: 0 = beat quality good, 1 = beat quality poor based on artifact in ECG channel.
E	Inter-Beat Interval	Inter-beat Interval.
F	Heart Rate	Beat to Beat Heart Rate (beats per minute).

2. _HR_epoch.csv

This file contains the second by second (epoch by epoch) heart rate based on ABM's Heart Rate algorithm.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)

C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	Beat Quality	1 or 0 value: 0 = beat quality good, 1 = beat quality poor based on artifact in ECG channel.
E	Inter-Beat Interval	Inter-beat Interval: Interpreted to the second
F	Heart Rate	Second to Second Heart Rate (beats per minute)

A.5 Z-Score Outputs

To remove individual variability from the various metrics, a z-score output is also provided. The Z-score for this purpose is calculated on the mean and standard deviation (SD) for at least the first 5 seconds, with additional epochs (seconds) added. The initial period to begin calculation is defaulted to 5 sec, but can be set by the user. A new mean and SD are computed if the raw data differs more than 2.5 SD from the mean. Epochs that are invalid will not be included in Z-score calculation. Instead the mean, SD, and z-score from a previous valid second are used.

After acquiring the configured period of valid seconds to determine the mean and SD, the ZScore algorithms begins computing the z-score for each epoch for input signal by:

ZScore = (Epoch value - mean)/ standard deviation

1. ZScore.csv

The ZScore.csv output file contains classification, workload, and heart rate information.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	class_higheng	Z-Score of High Engagement Probability (-99999 if it falls within Z-score computation window)
E	class_loweng	Z-Score of Low Engagement Probability (-99999 if it falls within Z-score computation window)
F	class_distraction	Z-Score of Class Engagement Probability (-99999 if it falls within Z-score computation window)
G	class_drowsy	Z-Score of Class Drowsy Probability (-99999 if it falls within Z-score computation window)
H	wl_fbds	Z-Score of Workload probability (FBDS model), where higher probability reflects higher WL (FBDS is best model for 85% of population)

		(-99999 if it falls within Z-score computation window)
I	wl_bds	Z-Score of Alternate Workload probability (BDS model): Not recommended for use, higher probability reflects higher WL (BDS Best WL model for other 15% of model) (-99999 if it falls within Z-score computation window)
J	wl_ave	Z-score of mean workload probability (mean of BDS and FBDS models), higher probability reflects higher workload (-99999 if it falls within Z-score computation window)
K	HeartRate	Z-Score of the second by second Heart Rate (-99999 if during Z score computation window)

2. _ZScore_PSD.csv

Z-scored info (same Z-scoring procedure as used for _ZScore output) for Heart Rate, and PSD info for 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) and 5 differential channels (FzPOz, CzPOz, FzC3, C3C4, F3Cz). The 5 differential channels available are fixed, based on the channels required for ABM's classification models.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	HeartRate	Z-Score of Heart Rate (-99999 if it falls within Z-score computation window) Interpreted to the second
E	OvRawRef_0	Z-score PSD (No Kaiser Window) for Theta Total (3-7Hz bins)
F	OvRawRef_1	Z-score PSD of (No Kaiser Window) for Alpha Total (8-12Hz bins)
G	poz_3	Z-scored PSD (No Kaiser Window) for Theta Total (3-7 Hz bin) at Channel POz
H	poz_6	Z-scored PSD (No Kaiser Window) for Alpha Total (8-12 Hz bin) at Channel POz
I	poz_7	Z-scored PSD (No Kaiser Window) for Beta (13-29 Hz bin) at Channel POz
J	poz_8	Z-scored PSD (No Kaiser Window) for Sigma (30-40 Hz bin at Channel POz
K-BJ		Z-Scored PSD for all 9 Referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) and 5 Differential channels using same naming conventions described above (FzPOz, CzPOz, FzC3, C3C4, F3Cz)

A.6 Actigraphy Outputs

1. Actigraphy.csv

The Actigraphy.csv output file contains both raw tilt data as well as the derived/processed data from the accelerometer.

Column	Column Name	Description
A	SessionNum	Session Name (.ebs File Name)
B	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)
C	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
D	X_Raw	Raw x-axis tilt value
E	X_Angle	X-axis Angle derived from tilt value
F	Y_Raw	Raw Y-axis tilt value
G	Y_Angle	Y-axis Angle derived from tilt value
H	Z_Raw	Raw Z-axis tilt value
I	Z_Angle	Z-axis Angle derived from tilt value
J	Movement_value	Sum of change in two dominant angles
K	Movement_Scale	Value between 0-5 derived from the change in two dominant angle using proprietary algorithm

A.7 Signal Quality Outputs

1. Artifact.csv

Artifacts (i.e., EMG, Eye blinks, Saturation, Spike, Excursion) detected in the signal.

Column	Column Name	Description
A	StartEpoch	.Start Epoch of the detected artifact
B	StartDP	Start Datapoint of the detected artifact
C	EndEpoch	End Epoch of the detected artifact
D	End DP	End Datapoint of the detected artifact
E	Artifact Type	Artifact type (0 - Spike, 1 - Excursion, 2 - Saturation, 3 - EMG, 5 - Eye blink)
F	Channel	Channel in which the artifact was detected (Eye blinks are reported in all channels, hence channel field is empty)
G	Rule	Artifact rule (reserved for internal debugging)

2. _missed_blocks.csv

This output file can be used to determine whether BT packets (or blocks) were dropped or missed during a data collection.

Column	Column Name	Description
A	sessionID	.ebs file Name
B	Blocks	Blocks: this increments for each blocks of lost packets, for example if packets 5,6,7 were missed and then 25,26,27,28 were missed, There will be two row entries in the csv file. Blocks will be 1 for former and 2 for late
C	Start Counter	Count when missed block started (6-bit counter in the headset (debugging)
D	End Counter	Count when missed block stopped (6-bit counter in the headset (debugging)
E	Epoch Start	Starting second (Epoch) of missed block
F	Offset Start	Starting Sample (datapoint or Offest) of missed block (in 1/256sec)
G	Epoch End	Ending second (Epoch) of missed block
H	OffsetEnd	Ending Sample (datapoint or Offest) of missed block (in 1/256sec)
I	Hour	Time of storing to file (or time of first packet AFTER missed blocks)
J	Minute	
K	Second	
L	Millisecond	

A.8 Create .def File Output Files

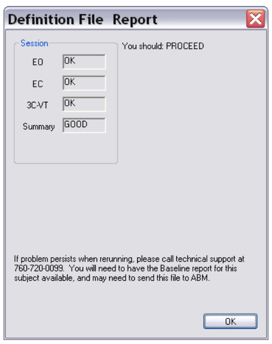
Running the "Create .def file" function from the B-alert Software will create 2 output files: a .def file and a BaselineReport.csv file.

1. **Definition File (xxxx_ M7003500_A1.def)**

   The Definition file is used to individualize the Engagement and Workload classification models. When a series of tasks conclude that include the three baseline tasks (or when the 'Create Definition File' function is invoked), then a Definition file (xxxx_M7003500_A1.def) will be generated. ***The Definition file should not be used directly for analysis***. It is solely used by the software to individualize the data for cognitive classification. Once a valid Definition file is created, it can then be used to classify Engagement and/or Workload for any EEG session for that participant.

2. **BaselineReport.csv** (**xxxxx_BaselineReport.csv**; where xxxxx- indicates subj ID + session ID)

This file summarizes performance, classification data, and PSDs (along with heart rate, if available) across the three baseline tasks: Eyes open (xxxxxx111.ebs), Eyes closed (xxxxxx121.ebs) and the 3 choice vigilance task (3CVT; xxxxxx231.ebs). Included are healthy, fully rested population norms (n=160) for all three aspects for comparison purposes. When a B-Alert Baseline has been completed, a definition file (used to individualize the classification models) and this baseline report automatically generate, and when processing has completed, a dialogue appears:



If any of the data is determined to be 'bad', the reasons for classifying the definition file as such, and suggested action, will be presented in this box. The Status of each task is based on a three part check: user performance, EEG data quality, and EEG classification breakdown. If a task or tasks are identified as being marginal or bad, ABM recommends re-rerunning the flagged tasks if time permits. After completing the re-run tasks, users can place all three valid tasks into the same folder, and then create a .definition file (.def) on those tasks. These performance and classification thresholds are designed to notify users when ABM identifies an EEG baseline that does not behave within normal ranges, indicating that the .definition file may not provide valid outputs. Users are encouraged to determine whether or not to use a .definition file using these reports and attempt to re-collect tasks if possible. These reports can also be used as justification for participant inclusion/exclusion.

If the definition file and baseline report generation are not automatically triggered, or fail for some reason, you can get them offline, by selecting the “create definition file” button and following the instructions in the manual. The dialogue summary will also appear when invoking the action offline.

The Baseline report contains the following information:

Cell(s)	Description	Notes
A1-B1	Data Quality based on performance	Subject's performance must fall within a given performance range (percent correct) for the definition file model to be valid.
A2-B2	Data Quality based on EEG data quality	This summarizes the quality in terms of artifacts (EMG, eyeblinks, spikes, excursions, etc.), and tells if enough good data was collected to determine a valid definition file model.

A5-E9	Performance Data- subject	Gives the number of responses (EO/EC) or percent of correct responses (3CVT), and lapses (single: missed, and mulitple:slow) for EO/EC, and Reaction time for 3CVT.
H5-K9	Population performance	The population norm performances.
A12-F15	Percentage of epochs (1sec periods) classified as one of the 4 brain state classifications by task	EO should primarily be low engagement, EC should be primarily distraction, and 3CVT should primarily be high engagement; you can calculate these using the # of epochs classified as a given classification : total valid epochs in the session.
G12-H15	Percentage of epochs that were not classified due to excessive EMG or INV (INV includes all other artifacts, such as spikes, excursions, etc.)	
I12-L15	Average probability of being classified as a given brain state	Based on our B-ALERT algorithm that uses the PSD values to classify each epoch; it also determines the probability.
M12-P15	Number of epochs classified as each brain state	
Q12-R15	Number of epochs not classified due to INV or EMG	
S12-T15	Number of Valid epochs and total epochs	
Rows 17-22	Population Classification percentages, probabilities and # of epochs	
Rows 24-47	Average log10 PSD values for FzPO and CzPO from Hz bin 1- 40	
Row 49-74	Population Average log10 PSD values for FzPO and CzPO from Hz bin 1-40	

3. Baseline Performance Thresholds

After completing the Baseline, the B-Alert software checks the participants on each of the baseline tasks to verify the user is no more than two standard deviations below the mean performance of the population (n = 200).

Baseline Task	EEG Performance Thresholds
Three Choice Vigilance Task (3C-VT)	***% Correct:*** **Mean:** 92 **SD:** 2.86 ***Reaction Time (RT):*** **Mean:** 0.745 **SD:** 0.056 **'Good' / 'OK':** ≥ 86.3 % Correct ≤ .857s Reaction Time **'Bad'/'Poor': >** 86.3 % Correct > .857s Reaction Time
Eyes Open (EO)	***'Good'/'OK' :*** MissedNmb + SlowRTNmb ≤ 5 **'Bad'/'Poor' :** MissedNmb + SlowRTNmb > 5
Eyes Closed (EC)	***'Good'/'OK' :*** MissedNmb + SlowRTNmb ≤ 5 **'Bad'/'Poor' :** MissedNmb + SlowRTNmb > 5

4. Brain State Baseline Classification Thresholds

After creating a definition file (.def), the B-Alert Software classifies the three baseline tasks and assesses whether the EEG classification metrics are within the normal population range for the tasks----an evaluation of whether or not the model is projected to accurately classify the individual.

Baseline Task	EEG Classification Thresholds
Three Choice Vigilance Task (3C-VT)	**'Good':** %High Engagement ≥ 71.5% **'Marginal':** 71.5% ≥ % High Engagement ≥ % 62% **'Bad':** % High Engagement < 61.99%
Eyes Open (EO)	**'Good':** % Low engagement ≥ 70% **'Marginal':** 69% ≥ % Low Engagement ≥ 62% **'Bad':** % Low Engagement < 62%
Eyes Closed (EC)	**'Good':** % Distraction ≥ 82% **'Marginal':** 82% > % Distraction ≥ 74% **'Bad':** % Distraction < 74%

A.9 Generate Reports Data Output Files

Running the "Generate Reports" function requires a .def file with the same subject # as the .ebs or .edf file you wish to create reports for. The .def file should be placed alongside the .ebs/.edf file. If you fail to create the desired reports during Real Time data collection, you can create them offline using either Generate Reports (see below) or Inspect EEG Record to utilize ABM's data analysis algorithms.

A.10 Classification Reports

1. EEC

EEC files will contain EEG classifications and heart rate for each epoch (1sec) of a given .ebs file. While the structure of the output file is different, the analysis procedures in .EEC files is the same as that in the Classification.csv.

Column	Label	Description
A	subj	Subject number.
B	sessnum	Session number.
C	epnum	Epoch Number.
D	C3C4Sat	Will have a 1 if epoch has a higher level of saturation artifact in the given channel. 0 = No artifact.
E	C3C4EMG	Will have an integer if epoch has a higher level of emg (muscle movement) artifact in the given channel 0 = No artifact
F	C3C4INV	Will have a 1 if epoch has a higher level of invalid artifact (all other artifacts) in the given channel. 0 = No artifact.
G	FzPOSat	Will have a 1 if epoch has a higher level of saturation artifact in the given channel. 0 = No artifact.
H	FzPOEMG	Will have an integer if epoch has a higher level of emg (muscle movement) artifact in the given channel. 0 = No artifact.
I	FzPOINV	Will have a 1 if epoch has a higher level of invalid artifact (all other artifacts) in the given channel. 0 = No artifact.

J	CzPOSat	Will have a 1 if epoch has a higher level of saturation artifact in the given channel. 0 = No artifact.
K	CzPOEMG	Will have an integer if epoch has a higher level of emg (muscle movement) artifact in the given channel. 0 = No artifact.
L	CzPOINV	Will have a 1 if epoch has a higher level of invalid artifact (all other artifacts) in the given channel. 0 = No artifact.
M	FzC3Sat	Will have a 1 if epoch has a higher level of saturation artifact in the given channel. 0 = No artifact.
N	FzC3EMG	Will have an integer if epoch has a higher level of emg (muscle movement) artifact in the given channel. 0 = No artifact.
O	FzC3INV	Will have a 1 if epoch has a higher level of invalid artifact (all other artifacts) in the given channel. 0 = No artifact.
P	F3F4Sat	Invalid for current configuration (-99999).
Q	F3F4EMG	Invalid for current configuration (-99999).
R	F3F4INV	Invalid for current configuration (-99999).
S	F3CzSat	Will have a 1 if epoch has a higher level of saturation artifact in the given channel.
T	F3CzEMG	Will have a integer if epoch has a higher level of emg (muscle movement) artifact in the given channel.
U	F3CzINV	Will have a 1 if epoch has a higher level of invalid artifact (all other artifacts) in the given channel.
V	original	INVALID- DO NOT USE.
W	ProbSleepOnset	Calculated probability that the epoch should be classified as Sleep Onset.
X	ProbDistraction	Calculated probability that the epoch should be classified as Distraction.
Y	ProbLowEng	Calculated probability that the epoch should be classified as Low Engagement.
Z	ProbHighEng	Calculated probability that the epoch should be classified as High Engagement.
AA	BrainState	The highest Probability in columns w, x, y, z will determine what the epoch is classified. Classifications are: .1: Sleep onset, .3: Distraction, .6: Low Engagement, .9: High Engagement. Seconds with excessive artifact where classification data could not be computed are labeled .05, . 1, or 2.
AB	#GoodChannels	Number of channels with enough good data to use.

AC	Good5chWorkload	.0 and 0.05 represent epochs in which there are < 5 good channels. These epochs will have 0 or 0.05 entered in the WL columns (AD-AG). It is important to *exclude* those epochs from analysis. A value of 1 means all 5 WL channels are good, so the WL prob is valid.
AD	RawProb5chWorkloadFBDS	Raw Workload probability, where higher probability reflects higher WL.
AE	SmoothProb5chWorkloadFBDS	Will be same as Raw WL probabilities (AD). Smoothing function is not currently supported.
AF	RawProb6chWorkloadBDS	Alternate WL model: Not recommended for use.
AG	SmoothProb5chWorkloadBDS	Same as AF. Smoothing function is not currently supported.
AH	HeartRate	Heart Rate (beats per min).
AI	HRVW1	INVALID- DO NOT USE.
AJ	HRVW2	INVALID- DO NOT USE.
AK	HRVW3	INVALID- DO NOT USE.
AL	HRVW4	INVALID- DO NOT USE.

2. _datasummary.csv

The data summary .csv contains summary classification information across an entire session.

Row	**Label**	**Description**
1	Column Label	Data
2	SUBJ	Subject #
3	SESSION ID	.ebs file name
4	Sleep Onset%	% of seconds (epochs) in session that Sleep Onset was the highest probability (in 4-Class B-alert Model)
5	Distracted%	% of seconds (epochs) in session that Distraction was the highest probability (in 4-Class B-alert Model)
6	Low Engagement%	% of seconds (epochs) in session that Low Engagement was the highest probability (in 4-Class B-alert Model)
7	High Engagement%	% of seconds (epochs) in session that High Engagement was the highest probability (in 4-Class B-alert Model)
8	Drowsy	Mean probability of Drowsy classification across the entire session
9	Sleep Onset(P)	Mean probability of Sleep Onset classification across the entire session
10	Distraction(P)	Mean probability of Distraction classification across the entire

		session
11	Low Engagement(P)	Mean probability of Low Engagement classification across the entire session
12	High Engagement(P)	Mean probability of High Engagement classification across the entire session
13	WLProbFBDS	Mean Workload probability (FBDS model), where higher probability reflects higher WL
14	WLProbFDS	Mean WorkLoad probability (BDS model): Not recommended for use, higher probability reflects higher WL

A.11 Heart Rate Reports

1. HR.csv

Second by Second (Epoch-by-epoch) heart rate data.

Column	Label	Meaning
A	Session	Session number
B	Epoch	Elapsed Second (Epoch)
C	HR	HR in the labeled second
D	HRVWindow1	Beat to Beat variability over a 20s window (by default). This output is experimental and not recommended for use by clients.
E	HRVWindow2	Beat to Beat variability over a 15s window (by default). This output is experimental and not recommended for use by clients.
F	HRVWindow3	Beat to Beat variability over a 10s window (by default). This output is experimental and not recommended for use by clients.
G	HRVWindow4	Beat to Beat variability over a 5s window (by default). This output is experimental and not recommended for use by clients.

2. Summary_HR.csv

Summary heart rate data over the entire session.

Columns	Label	Description
A	Session	Session number
B	HR	HR averaged over entire session
C	HRVWindow1	Beat to Beat variability over a 20s window (by default). This output is experimental and not recommended for use by clients.
D	HRVWindow2	Beat to Beat variability over a 15s window (by default). This

		output is experimental and not recommended for use by clients.
E	HRVWindow3	Beat to Beat variability over a 10s window (by default). This output is experimental and not recommended for use by clients.
F	HRVWindow4	Beat to Beat variability over a 5s window (by default). This output is experimental and not recommended for use by clients.
G	HRQ1	Average HR for the 1st 5min Quartile (Only valid for 20min 3C-VT AMP task).
H	HRQ2	Average HR for the 2nd 5min Quartile of 20min (Only valid for 20min 3C-VT AMP task).
I	HRQ3	Average HR for the 3rd 5min Quartile of 20min (Only valid for 20min 3C-VT AMP task).
J	HRQ4	Average HR for the 4th 5min Quartile of 20 min (Only valid for 20min 3C-VT AMP task).
K	HRV_20_Q1	20sec PSD based HRV for first 5 min. This output is experimental and not recommended for use by clients.
L	HRV-20_Q2	20sec PSD based HRV for second 5 min. This output is experimental and not recommended for use by clients.
M	HRV-20_Q3	20sec PSD based HRV for third 5 min. This output is experimental and not recommended for use by clients.
N	HRV-20_Q4	20sec PSD based HRV for fourth 5 min. This output is experimental and not recommended for use by clients.
Repeats quartile data for other HRV windows. These outputs are experimental and not recommended for use by clients.		

3. HRV.csv

Heart Rate Variability data averaged over each 5-minute window in the session.

Column	Label	Description
A	Session	Session number
B	Window Length	Set to 5-min windows
C	Window Increment	Iterates in 5-min increments
D	OrderNumber	Iterates in 5-min increments, Total = entire session
E	Epochs	# of epochs included in window
F	Total Power	Sum of Power from 0-.5Hz (a measure of variability, equivalent to the SD of HR)
G	VLF	Very Low Frequency (0.01Hz-0.04Hz)
H	LF	Low Frequency (0.04Hz-0.15Hz)
I	LFNorm	LF/total power (% of total power) (Indication, primarily, of Sympathetic activity)
J	HF	High Frequency (0.015Hz to 0.4Hz)
K	HFNorm	HF/total power (% of total power) (Indication of Parasympathetic Activity)

L	LFHFRatio	LF:HF Ratio (Parasympathetic vs. Sympathetic activity ratio) -- Recommended HRV variable for use[1,2,3]

1. Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Eur Heart J. 1996;17(3):354-81.
2. Baron R, Ewing DJ. Heart rate variability. The International Federation of Clinical Neurophysiology. Electroencephalography Clinical Neurophysiology Suppl. 1999;52:283-6.
3. Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Circulation. 1996;93(5):1043-65.

4. PSD_HRV.csv

Contains the ECG (EKG) Power Spectral densities for each 5min interval from .01 - .40Hz.

Columns	Label	Description
A	Session	Session number
B	Window Length	Set to 5-minute windows
C	Window Increment	Iterates in 5-min increments
D	OrderNumber	Iterates in 5-min increments, Total = entire session
E	Epochs	# of seconds (epochs) included in window
F	.01Hz	ECG PSD for the .01Hz bin
G	.02Hz	ECG PSD for the .02Hz bin
H-AS	.03Hz-.40Hz	ECG PSD for the .03Hz - .40Hz bin

A.12 Power Spectral Density Reports

1. .psd

PSDs are computed for each second of a given session. All PSD outputs are in μV^2. Both .psd files will contain the Absolute along with the Relative PSD information for each channel configuration (either _ref or _class). Absolute PSD is equal to log10(X) for each X Hz bin each second. Relative PSD is equal to [log10(sum3-40hz) - log10(X)] for each X Hz bin. PSDs for each epoch are an average of 3 1-second overlays: one starting .5 sec before the epoch, the second starting at the same time as the epoch, and the last starting .5 sec after the epoch. Files labeled as "_ref" will have the PSDs for all the referential channels recorded in the .ebs file (x10 standard montage: F3,Fz,F4,C3,Cz,C4,P3,PO,P4). "_Class" has PSDs for the *differential channels* that are computed for generating ABM's classifications: FzPO, CzPO, FzC3, C3C4, F3Cz. These .psd outputs do NOT have the Kaiser windowing procedure.

Columns	Label	Description
A	subj	Subject number
B	sessnum	Session number
C	epnum	Epoch Number
D	Hz3X	Power for 3Hz bin at site X
E	Hz4X	Power for 4Hz bin at site X
F-AO	Hz5-40 X	Power for 5-40Hz bins at site X
AP	R3X	Relative power [log10(sum3-40hz) - log10(3)] for 3Hz bin at site X
AQ-CA	R4-R40 X	Relative power for 4-40Hz bins at site X
CB	ED317 X	Log10(Sum(Psd3Hz:Psd17Hz)) at X
CC	EDC324 X	Log10(Sum(Psd3Hz:Psd24Hz)) at X
CD	X-ThetaSlow (3-5)	Theta slow (avg. Power of 3-5Hz) for channel X
CE	X-ThetaFast (5-7)	Theta fast (avg. Power of 5 - 7Hz) for channel X
CF	X-ThetaTotal (3-7)	Total Theta (avg. power of 3 - 7Hz) for channel X
CG	X-AlphaSlow(8-10)	Alpha slow (avg. power of 8 - 10Hz) for channel X
CH	X-AlphaFast(10-12)	Alpha fast (avg. power of 10 - 12 Hz) for channel X
CI	X-AlphaTotal(8-12)	Total Alpha (avg. power of 8 - 12 Hz) for channel X
CJ	X-Beta(13-20)	Total Beta (avg power of 13-20 Hz) for channel X
CK	X-Gamma (21-30)	Total Gamma (avg power of 21-30 Hz) for channel X
CL	X-Sigma (31-40)	Total Sigma (avg power of 31-40 Hz) for channel X
CM.....		Same information described above will be present for all channels _REF.psd = F3,Fz,F4,C3,Cz,C4,P3,PO,P4, if _Class.psd = FzPO, CzPO, FzC3, C3C4, F3Cz

2. .SBW

.SBW contains summary bandwidth information. These files have Bandwidth data for all channels in an .ebs file averaged across the entire session length. In an AMP task, Column C (DataType) indicates which portion of the AMP task* (i.e., the identification tasks for the B-

Alert definition file calculations: Eyes open, Eyes closed, and 3CVT). Files labeled as _ref will have the PSDs for all the referential channels recorded in the .ebs file (x10 standard montage: F3, Fz, F4, C3, Cz, C4, P3, PO, P4). _Class has PSDs for the *differential channels* that are computed for generating ABM's classifications: (FzPO, CzPO, FzC3, C3C4, F3Cz).

- Amp tasks such as the 3CVT have a practice session in which the subject learns the task in order to remove potential learning effects from the overall task. The data from the practice portions are separated from the testing portion in these files.

Bandwidth Name	Hz Bins
ThetaSlow	3-5
ThetaFast	5-7
ThetaTotal	3-7
AlphaSlow	8-10
AlphaFast	10-12
AlphaTotal	8-12
Beta	13-20
Gamma	21-30
Sigma	31-40

Column	**Label**	**Description**
A	subj	Subject number
B	sessnum	Session number
C	Data Type	For AMP tasks only: Indicates which portion of AMP task the data is taken from; the values vary for each AMP task. 0 = entire session, .2 = testing, .5= 1st practice. .4=practice training, .6= 2nd practice training, .7 = 2nd practice testing, .8 = 3rd practice training, .9 = 3rd practice testing.
D	X-ThetaSlow (3-5)	Theta Slow (avg. power of 3-5Hz bins) for channel X
E	X-ThetaFast (5-7)	Theta Fast (avg. Power of 5-7Hz bins) for channel X
F	X-ThetaTotal (3-7)	Total Theta (avg. Power of 3-7Hz bins) for channel X
G	X-AlphaSlow(8-10)	Alpha slow (avg. Power of 8-10Hz bins) for channel X
H	X-AlphaFast(10-12)	Alpha fast (avg. Power of 10-12 Hz bins) for channel X
I	X-AlphaTotal(8-12)	Total Alpha (avg. Power of 8-12 Hz bins) for channel X
J	X-Beta(13-20)	Total Beta (avg. Power of 13-20 Hz bins) for channel X
K	X-Gamma (21-30)	Total Gamma (avg. Power of 21-30 Hz bins) for channel X

L	X-Sigma (31-40)	Total Sigma (avg. Power of 31-40 Hz bins) for channel X
M	Y-ThetaSlow (3-5)	Theta slow (avg. Power of 3-5Hz bins) for channel Y

3. .EBW

Two .EBW files (_Ref and _Class) contain second by second (or epoch by epoch) PSD bandwidth data. The .ebw files contain the PSD bandwidth data for all channels in a given .ebs file. Each Bandwidth indicates the average power across each bin within that bandwidth. Files labeled as _REF will have the PSDs for all the referential channels recorded in the .ebs file (F3, Fz, F4, C3, Cz, C4, P3, PO, P4). _Class has PSDs for the *5 differential channels* that are computed for generating ABM's classifications: (FzPO, CzPO, FzC3, C3C4, F3Cz).

Bandwidth Name	Hz Bins
ThetaSlow	3-5
ThetaFast	5-7
ThetaTotal	3-7
AlphaSlow	8-10
AlphaFast	10-12
AlphaTotal	8-12
Beta	13-20
Gamma	21-30
Sigma	31-40

Column	**Label**	**Meaning**
A	Subj	Subject number as entered
B	Sessnum	Session number
C	epnum	Epoch Number
D	Sex	Gender (not currently supported)
E	XSat	Will have a 1 if epoch has a higher level of saturation artifact in the given channel 'X'
F	XEMG	Will have an integer if epoch has a higher level of emg (muscle movement) artifact in the given channel 'X'
G	CXINV	Will have a 1 if epoch has a higher level of invalids artifact (all other artifacts) in the given channel 'X'
Artifact info in E-G Repeats for all channels		
AC	epclass	Identifies the type of task, if an AMP task - no longer supported, do not use
AD	Blink	if an eye blink was detected, will have a 1
AE	X-ThetaSlow(3-5)	For labeled channel, average power in 3-5 Hz

AF	X-ThetaFast(5-7)	For labeled channel, average power in 5-7 Hz
AG	X-ThetaTotal(3-7)	For labeled channel, average power in 3-7 Hz
AH	X-AlphaSlow(8-10)	For labeled channel, average power in 8-10 Hz
AI	X-AlphaFast(10-12)	For labeled channel, average power in 10-12Hz
AJ	X-AlphaTotal(8-12)	For labeled channel, average power in 8-12 Hz
AL	X-Beta(13-20)	For labeled channel, average power in 13-20 Hz
AM	X-Gamma(21-30)	For labeled channel, average power in 21-30 Hz
AN	X-Sigma(31-40)	For labeled channel, average power in 31-40 Hz
Repeats for all channels…		_Ref.ebw(F3,Fz,F4,C3,Cz,C4,P3,PO,P4) _Class.ebw (FzPO, CzPO, FzC3, C3C4, F3Cz)