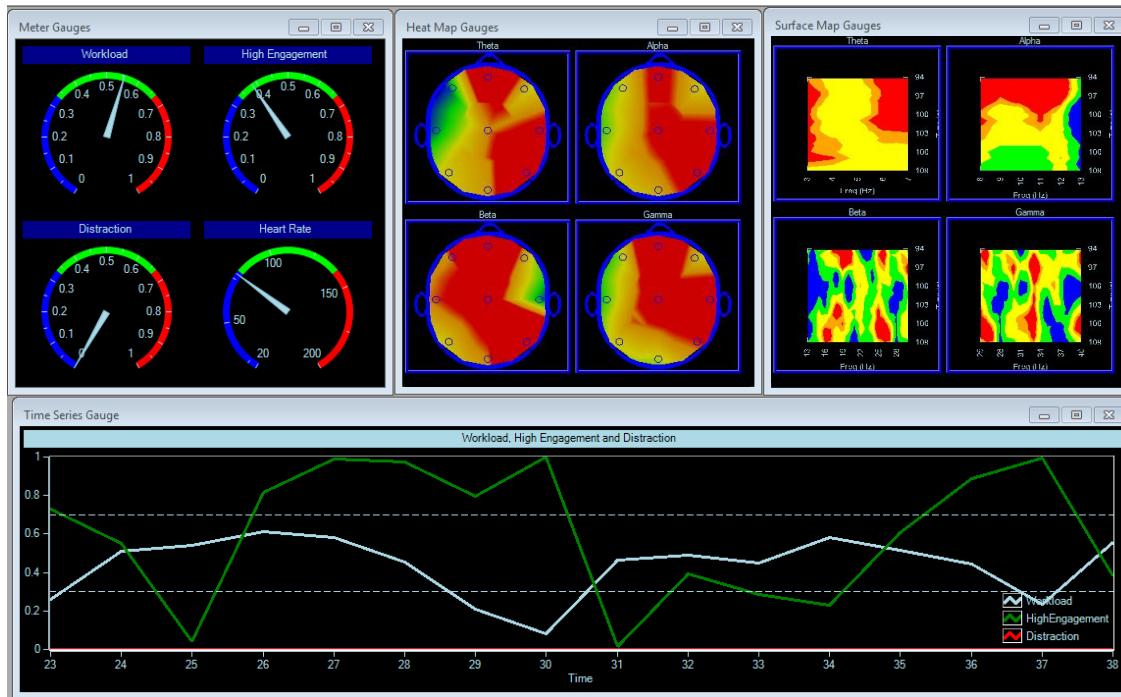


# B-Alert Software Manual

v. 1.4



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## Introduction

Welcome to the B-Alert® Software Manual. The purpose of this guide is to familiarize *AcqKnowledge* users with Advanced Brain Monitoring Inc.'s optionally licensed B-Alert® Cognitive States Analysis software. In addition to the *AcqKnowledge* with B-Alert installation, this licensing level includes stand-alone B-Alert "Live" software, accessible via a separate B-Alert Desktop shortcut.

Access to B-Alert features integrated with *AcqKnowledge* software (as well as basic B-Alert wireless hardware setup) is explained in the **Biopac *AcqKnowledge* Software Guide** and the **B-Alert with *AcqKnowledge* Quick Guide**.

Please note that in order to use B-Alert in conjunction with *AcqKnowledge*, the integrated B-Alert software controls must be accessed within the *AcqKnowledge* application.

The explanations found in this manual demonstrate Advanced Brain Monitoring Inc.'s proprietary B-Alert software as functioning independently from the *AcqKnowledge* application. Therefore some of the dialogs and functionalities will vary from those generated by using B-Alert within the *AcqKnowledge* user interface.

For a full explanation of the B-Alert wireless EEG hardware and hardware setup, please refer to the **B-Alert® X24/X10 User Manual**.

- For step-by-step direction, request **B-Alert User Training Videos** from [support@biopac.com](mailto:support@biopac.com).

## 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 7 or higher operating system
- .NET framework version 3.5 installed
- Minimum of 50 MB hard disk space per 5-hour session
- VGA or higher resolution video adapter
- One available USB port (two for validation)
- Monitor size between 15" and 21" required for Metric Benchmarking Sessions

## Chapter 1: B-Alert Graphical User Interface (GUI)

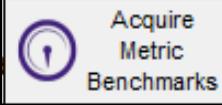
### 1.1 ABM data acquisition devices and peripherals



### 1.2 Overview of Online Data Acquisition Actions

The B-Alert Live acquisition Software has five Online Action icons located in the upper left corner of the home 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 grouped to the right and enable functions related to data handling for previously recorded signals. See *Chapter 5: Data Analysis and Review* for detail on Offline Actions.

Online Actions					Offline Actions				
	Acquisition		Acquire & Retransmit		View Retransmitted		Acquire Metric Benchmarks		Test Impedance
	Acquisition	The <b>Acquisition</b> function allows users to start/stop data acquisition with their selected mobile EEG device. The communication port is automatically detected, and the Headset Configuration is automatically informed.							
	Acquire & Retransmit	The <b>Acquire &amp; Retransmit</b> function allows users to begin data acquisition with their selected mobile EEG device 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. <b>Note:</b> when using this function, data is only stored on the primary computer (not on the secondary machine).							
	View Retransmitted	The <b>View Retransmitted</b> 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.							

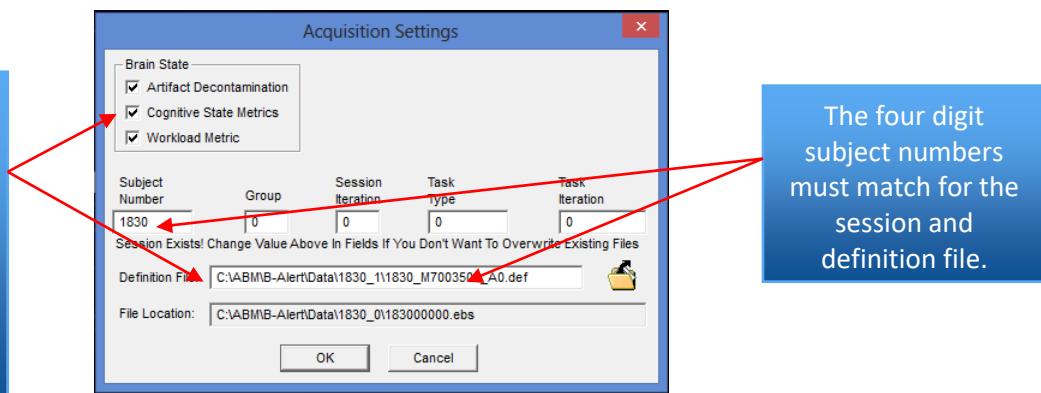
	<p>The <b>Acquire Metric Benchmarks</b> function allows the experimenter to run the three tasks required for creating an individual subject's unique definition file (.def file). In order to ensure the validity and accuracy of the Cognitive State and Workload Metrics on a subject, that individual must run the Benchmarks one time when fully rested. Completing them will automatically generate their specific definition file. The three tasks include:</p> <ul style="list-style-type: none"> <li>• 3-Choice Vigilance Task for High Engagement and Workload</li> <li>• Auditory Psychomotor Vigilance Task for Low Engagement</li> <li>• Visual Psychomotor Vigilance Task for Distraction</li> </ul>
	<p>The <b>Test Impedance</b> function allows the user to test the impedance levels at each electrode site. Low impedance (&lt;40 kΩ) is recommended 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.</p>

### 1.3 Acquisition

Before starting an Acquisition, plug the B-Alert USB Receiver into the PC and switch ON the headset. 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 "Acquisition" 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 the Cognitive State and Workload Metrics in real-time, select the appropriate check boxes. Artifact Decontamination is essential for Cognitive State and Workload metric classifications and will be automatically selected. Select the definition file (.def) 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. If your computer appears to be computationally over stressed, you may wish to deselect real-time Artifact Decontamination, Cognitive State Metric, and Workload Metric processing (but please note that only raw data will be displayed and stored).

To obtain Cognitive State Metrics and Workload Metric, the Benchmarks create a unique definition file for each subject previously created.



The four digit subject numbers must match for the session and definition file.

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:

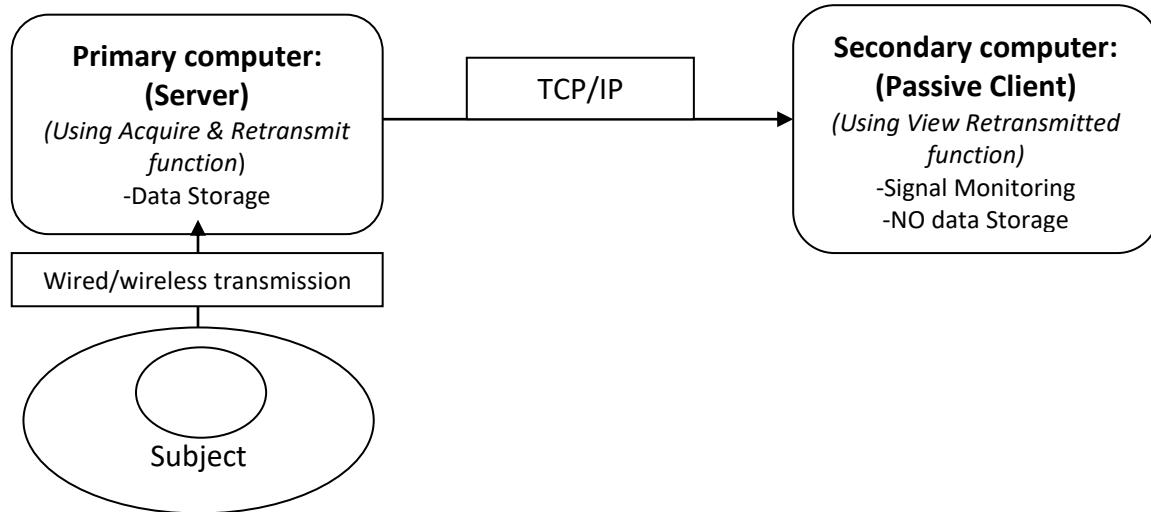
If the combination of Subject/Session/Group/Task numbers is identical to a previous acquisition, all files will be overwritten. A warning window will appear to prevent accidental overwrite.

**Note:**

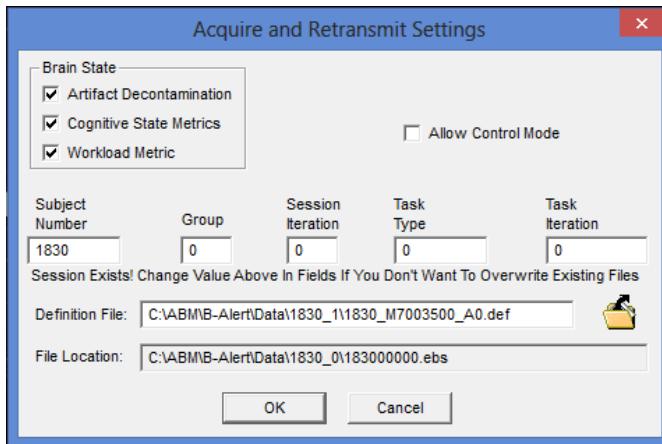
Some device configurations may not support all processed parameters.

## 1.4 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.

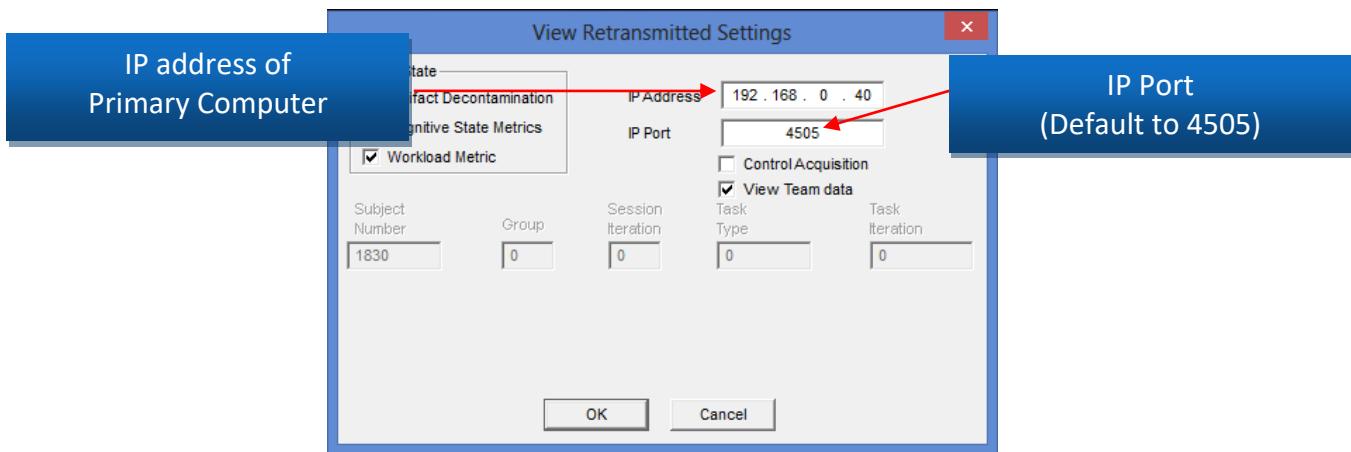


Before starting Acquire & Retransmit, plug the B-Alert USB Receiver into the primary computer and switch ON the headset. Wait for the solid green LED pattern on the headset and solid LED pattern on B-Alert USB Receiver to confirm the Receiver and Headset have connected. On the primary computer, click 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-based Metrics in real time during data acquisition.



## 1.5 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:

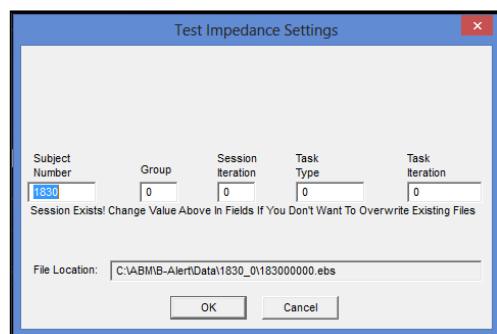
- Open the Start Menu and select the Run option.
- In the Run window, type "cmd".
- When the command prompt window opens, type "ipconfig" and click enter.
- The IP Address will be presented.
- Enter this IP Address into the IP Address field on the secondary computer.

If the connection is unsuccessful:

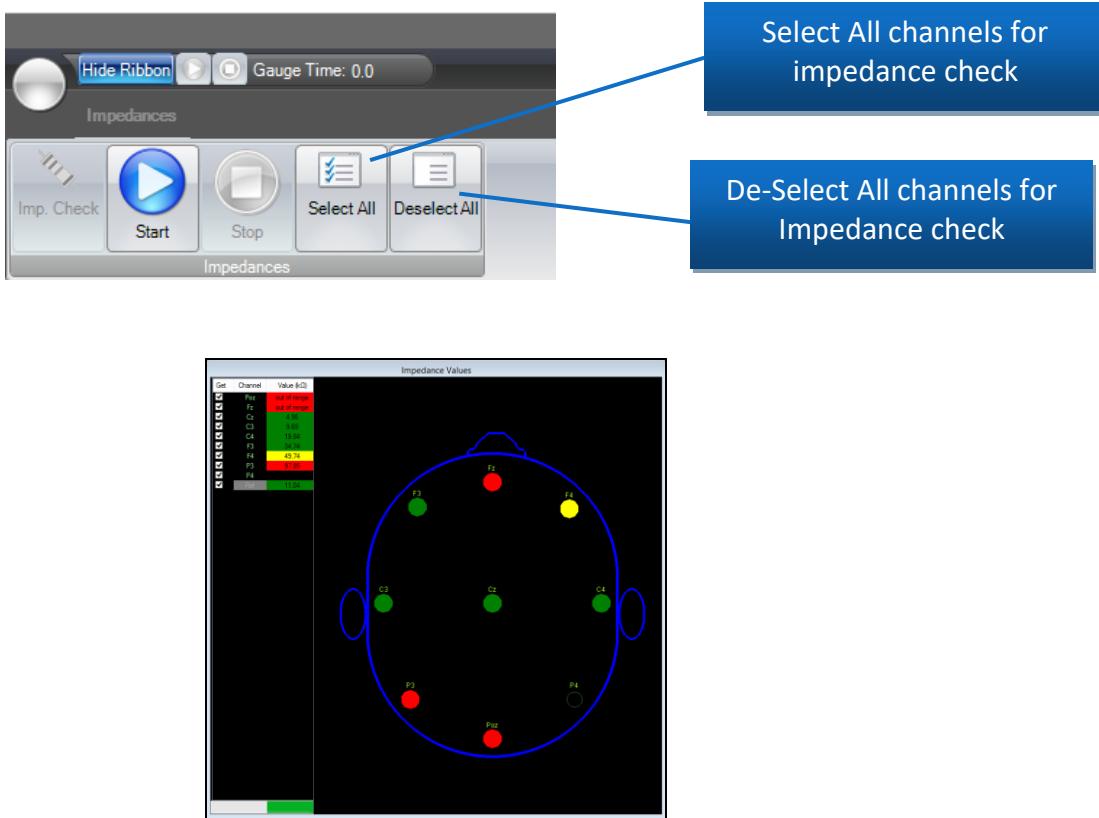
- 1) Check firewall settings of both primary and secondary computer. Turn the firewall off (not recommended), or provide access to B-Alert Live software
- 2) Change the IP Port Number on the primary computer, and update the number accordingly on the secondary computer (using Settings/Configure Data Streaming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

## 1.6 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  $k\Omega$ , 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 switch ON the headset. 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.



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



Impedance values  $< 40\text{k}\Omega$  will be highlighted in green, values  $40\text{k}\Omega - 80\text{k}\Omega$  will be yellow, and impedance values  $> 80\text{k}\Omega$  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  $40\text{k}\Omega$  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  $40\text{k}\Omega$  (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 impedances will impact negatively *all* EEG impedance measurements. To reduce time during troubleshooting, 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.

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

- *xxxxxxxxxx.xxxxxx.xxxxxx.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.
- *xxxxxxxxxx.xxxxxx.xxxxxx.Impedance.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.

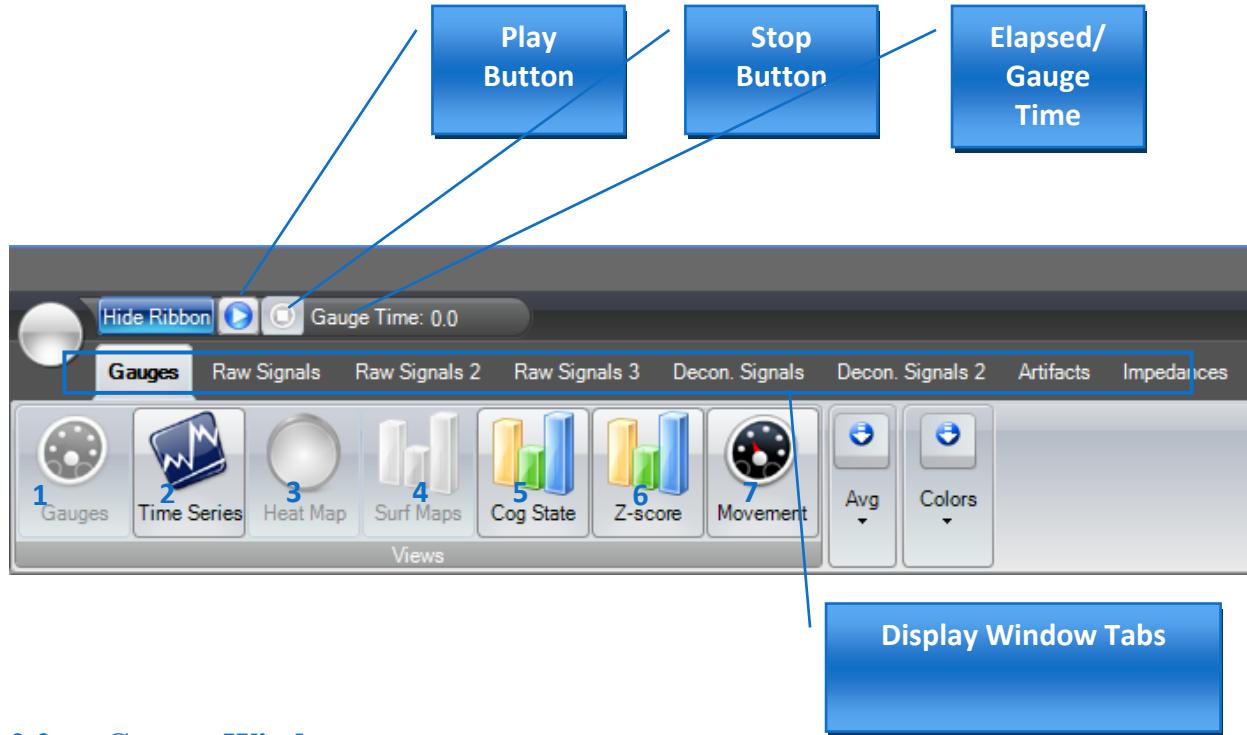
## 1.7 Acquire Metric Benchmarks

The Acquire Metric Benchmarks function allows the experimenter to run the three tasks required for definition file (.def file) creation: 3-Choice Vigilance task (3CVT), Auditory Psychomotor Vigilance Task (APVT), and Visual Psychomotor Vigilance Task (VPVT). See

## Chapter 2: B-Alert Gauges GUI

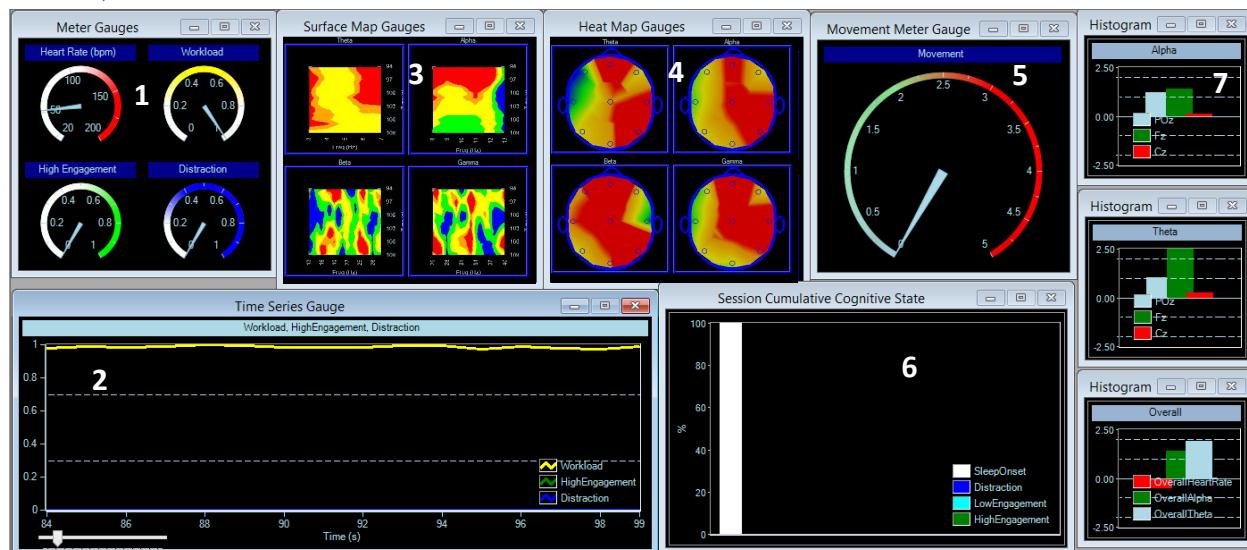
### 2.1 B-Alert GUI Overview

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.



### 2.2 Gauges Window

The gauges are customizable so that experimenters can view data and Metrics in a way most meaningful to the nature of their testbed. The default gauges include the High Engagement and Distraction classifications from the Cognitive State Metrics, as well as the Workload Metric, and Heart Rate (when acquired). Heat maps display EEG power spectral densities (PSDs) in both spatial and temporal maps for the traditional Hz bands (i.e., Beta, Alpha, Theta, and Gamma).



- Meter Gauges:** These include the High Engagement and Distraction classifications from the Cognitive State Metrics, as well as the Workload Metric, and Heart Rate (when acquired). For the Metrics, the default presentation setting is second-by-second changes averaged on a trailing 3-second window. For users with longer duration testbeds, it may be helpful to reduce the sensitivity of the Metrics with the “Avg” button. Here, users can display more meaningful outputs by varying the sensitivity from two to thirty seconds.
- Time Series:** Shows z-scored values (updated every second) in a 15-second window. Three views are selectable: (1) Workload, High Engagement, and Distraction (default); (2) Drowsy, Low Engagement, and High Engagement; and (3) Overall Heart Rate, Overall Alpha, and Overall Theta.
- Surface Map:** Shows z-scored time history (5-sec) of the PSDs of individual bins calculated across all the channels.
- Heat Map:** Shows 4-second averaged distribution of PSDs for the specified EEG band across the scalp. The PSDs are computed from decontaminated data (if available), smoothed using Kaiser-window, and averaged across 3-epoch overlays. Default bands are: Theta (3-7 Hz), Alpha (8-13 Hz), Beta (13-29 Hz), and Gamma (25-40 Hz).
- Movement:** Shows movement scale computed from the change in the dominant angles of the 3-axis accelerometer.
- Cog State:** Shows the relative percentage of each Cognitive State Metric for the cumulative session. Please note the inverse relationship between each of the classifications.
- Z-Score:** Shows z-scored second-by-second values of EEG Bands for specified electrodes in histogram format. Three default views are available: (1) POz, Fz, Cz for Theta band; (2) POz, Fz, Cz for Alpha band; and (3) Overall Alpha and Theta across all channels and HR.

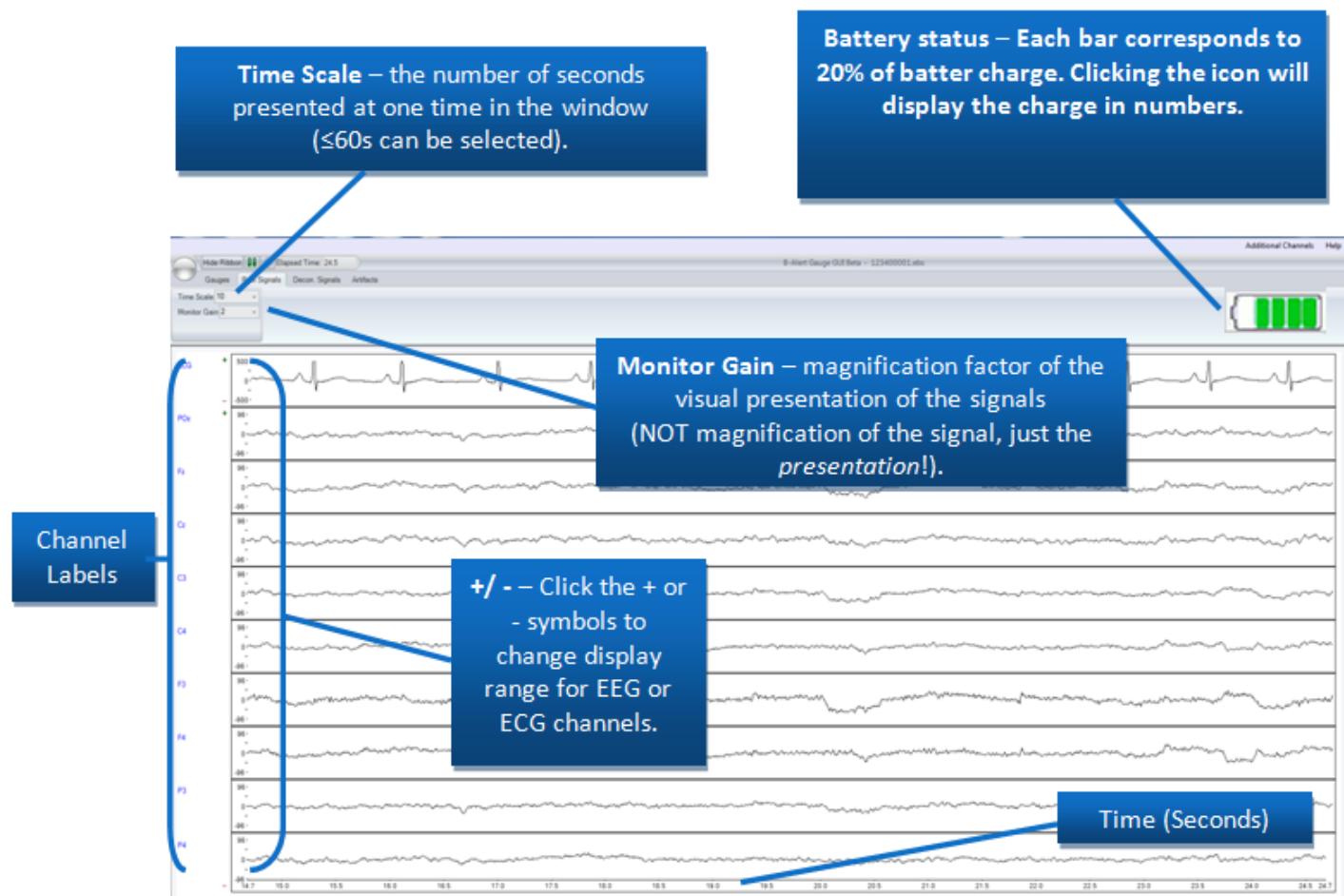
**Note:**

The availability of the gauges depends on the type of the device and brain state processing selected. For example:

- 1) Workload Metric classification is not available for the B-Alert X4, as it does not include sufficient electrode site coverage.
- 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.

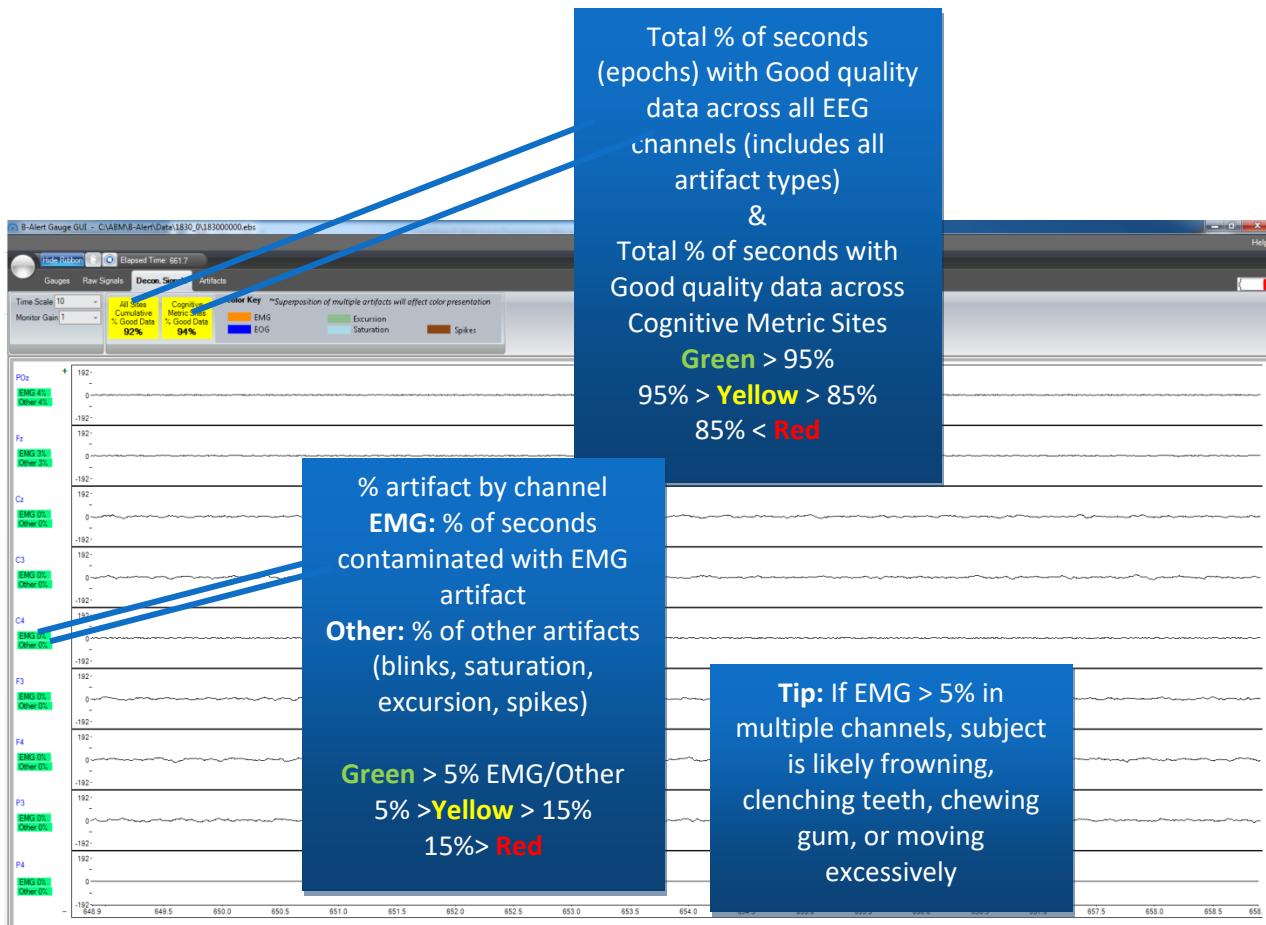
## 2.3 Raw Signals Window

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



## 2.4 Decon. Signals Window (Decontaminated Signals)

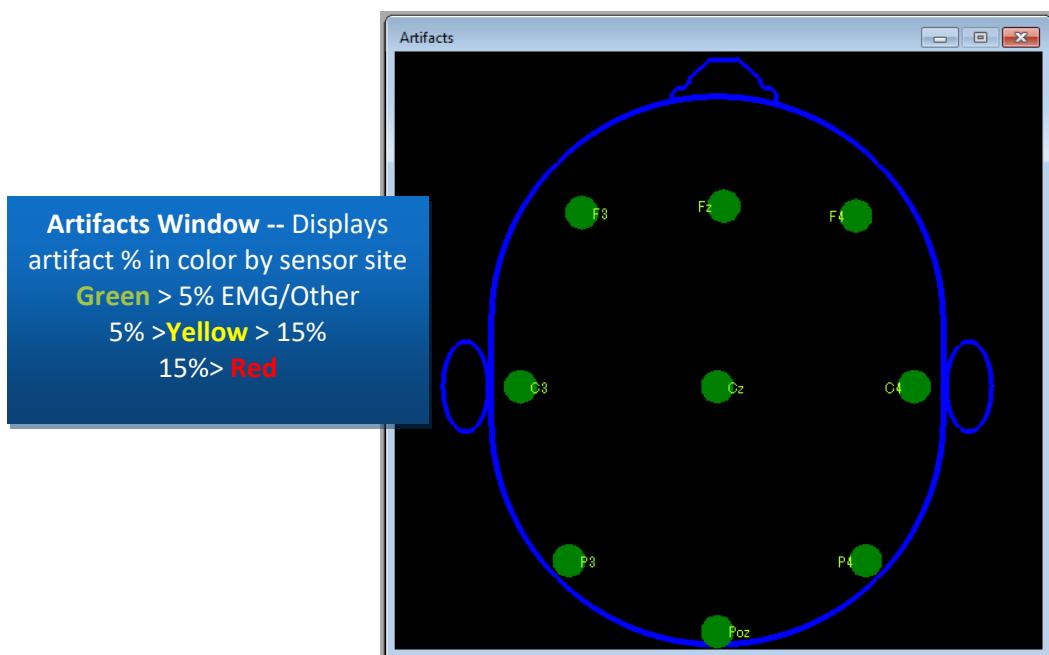
The Decon Signals window visualizes EEG signals using ABM's validated Artifact identification and decontamination algorithms which identify and remove 5 artifact types: EMG, EOG, excursions, saturations, and spikes. The use of overlaid windowing and data computation results in an approximately 2.5 - 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: Data 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. B-Alert Live does not employ any artifact decontamination procedures for the ECG channel. The data quality indicators (color and percentages) are built for the EEG-based Metrics--- these values may not be appropriate data quality measures for some EEG applications.



**Tip:** Click on the “Cognitive Metric Sites % Good Data” Flag on the toolbar to change to “Workload Metric Sites % Good Data”

## 2.5 Artifacts Window

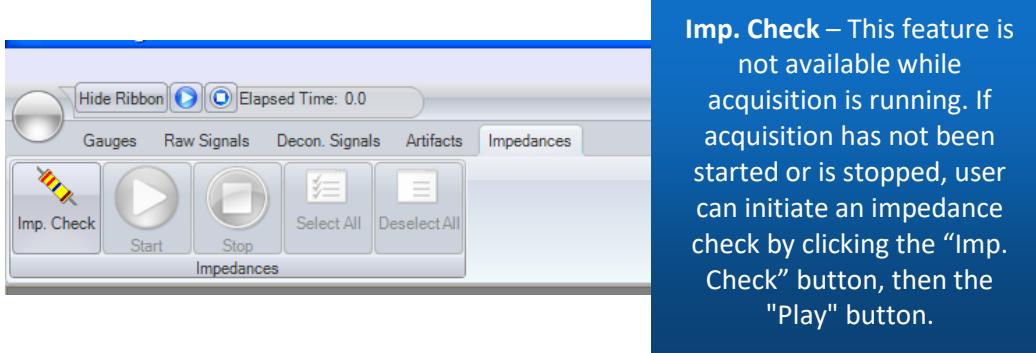
The artifacts window displays the color-coded artifact percentages for each sensor site.



**Note:** This artifact window displays sensors for an x10 model.

## 2.6 Impedances Window

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



## 2.7 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 marker appears on screen across channels)
- Shift + E – Stop marker (Red marker appears on screen across channels)

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 (Refer Section 9) during offline analysis.

**Note:**

- 1) The markers area available only on the “Raw Signals” tab.
- 2) The markers are synchronized, i.e. Shift+E will be active only after Shift+S.

## Chapter 3: Acquiring Metric Benchmarks

### 3.1 Metric Benchmark Tasks

The acquisition of baseline data (Metric Benchmark) is used to create the individualized EEG profiles required for the Cognitive State and Workload Metrics to be valid and accurate across individuals. Each complete Benchmarking Session includes three distinct tasks:

- 3-choice vigilance task (3CVT)
- Visual Psychomotor Vigilance Task (VPVT)
- Auditory Psychomotor Vigilance Task (APVT)

Three durations are supported that vary in increasing order of classification accuracy:

- Short\_Benchmark: Takes around **9-10** minutes to complete
- Medium\_Benchmark: Takes around **15** minutes to complete
- Long\_Benchmark: Takes around **30** minutes to complete

Typically, benchmark 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.

**Note:** Standard lengths of the session may be appended with additional time if the user fails to respond consistently (suggesting they are fatigued or fell asleep, and thereby distorting the baseline measures).

### 3.2 Steps for Acquiring Metric Benchmarks

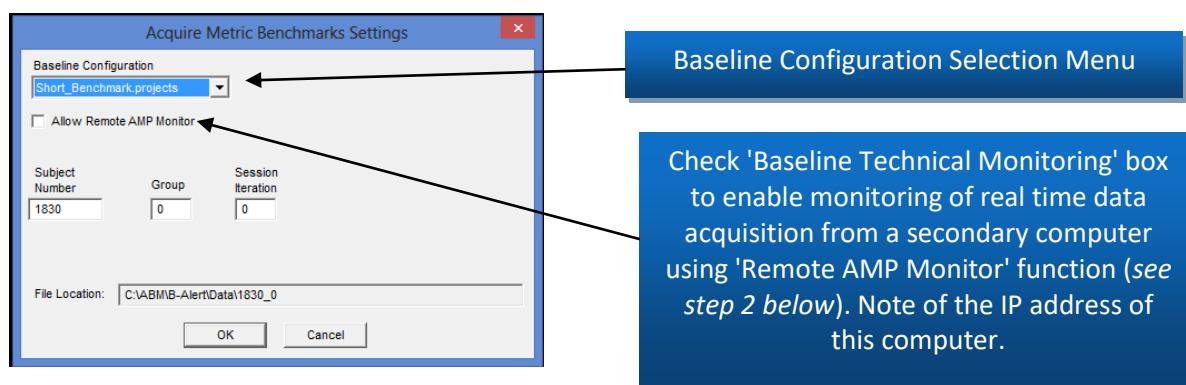
#### 1. Acquire Metric Benchmark

Click the "Acquire Metric Benchmark" 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 Benchmarking sessions. All EEG data for benchmarking is captured in \*Signals.Raw.edf file. All event data is captured individually for each task. Each task will output an \*Events.edf

Example:

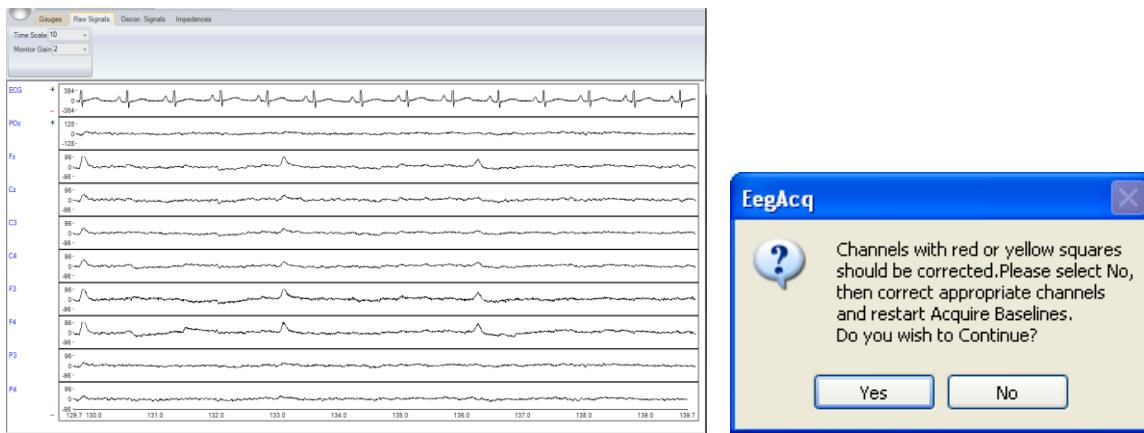
 000100000.270515.102423.3CVTLong\_amp.Events.edf

Notice: The first 9 digits are determined by the configuration described above. The next 6 digits are determined by the date of acquisition. The next 6 digits are determined by the time of acquisition. The next descriptor preceding .Events.edf explains the corresponding benchmark task.

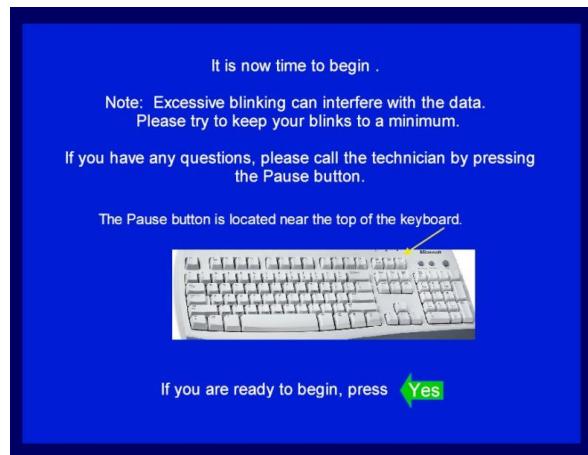


After entering the session information, BLS will automatically perform a 60-second signal quality/artifact check (press the blue PLAY icon to view data during 60 second check). During this time, the signals presented on the screen should be visually inspected to see if EEG, EMG, and ECG signals are properly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

## B-Alert Software Manual



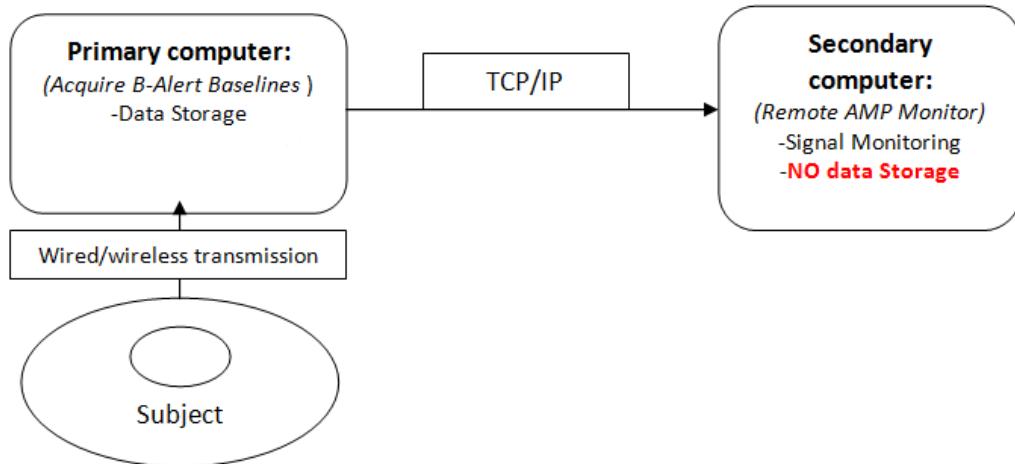
After a quality check is completed, the task will start. The following window will be shown; press the **left arrow** button on the keyboard to begin the task.



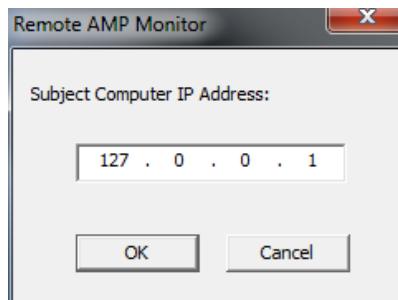
**Note:** It is highly recommended to perform an impedance check and to make sure that all channels are in the Green before starting the Metric Benchmarks task.

## 2. Monitoring Signal During Benchmarking Tasks (Available only for X24 & X10)

When possible, ABM strongly encourages technicians to monitor the data quality of signals throughout the Benchmarking Tasks 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 Benchmarking Tasks over TCP/IP. **Note:** Data on secondary computer will be *only* visualized (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. *Remote 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.*

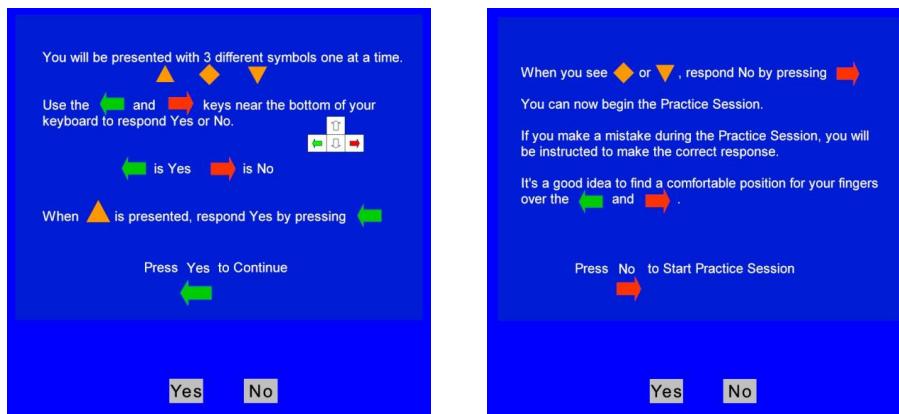


A 'Remote AMP Monitor' pop-up window will appear with a text box to allow users to enter in the IP address of the primary computer (i.e., the PC running Acquire Metric Benchmarks). Enter the IP, and then click 'OK' to launch the monitor. The Remote AMP monitor display utilizes functions from an older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

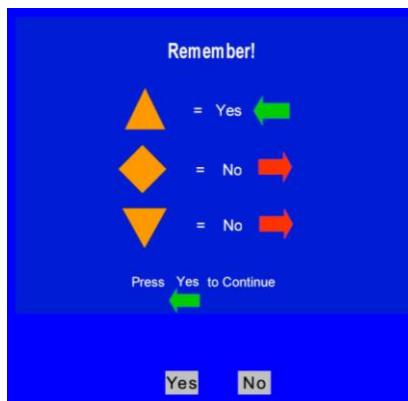
### 3. Completing the Benchmarking Tasks

The subject will be prompted to complete at least three neurocognitive tests. Each task itself is an abbreviated version of similar tasks from ABM's Alertness & Memory Profiler comprehensive assessment software. The standard session length for the tasks may be appended with additional time if the user fails to respond consistently (suggesting they are fatigued or fell asleep, and thereby distorting the baseline measures).

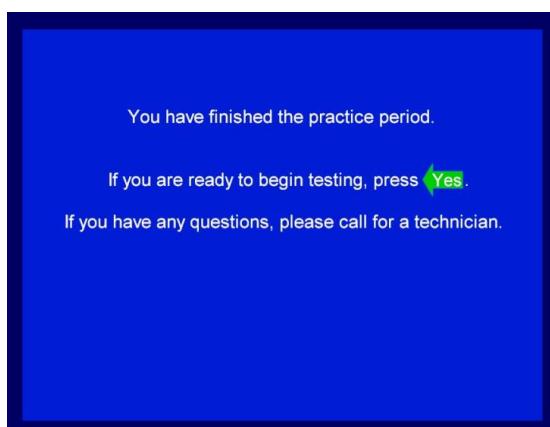
a. **3CVT:** After the instructions are presented, the **3-Choice Vigilance Task** begins with a Practice Session:



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

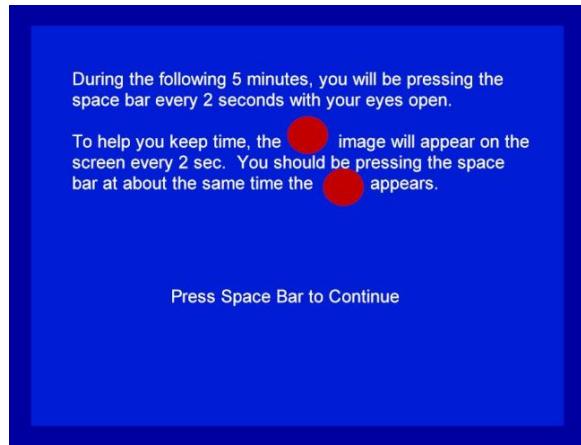
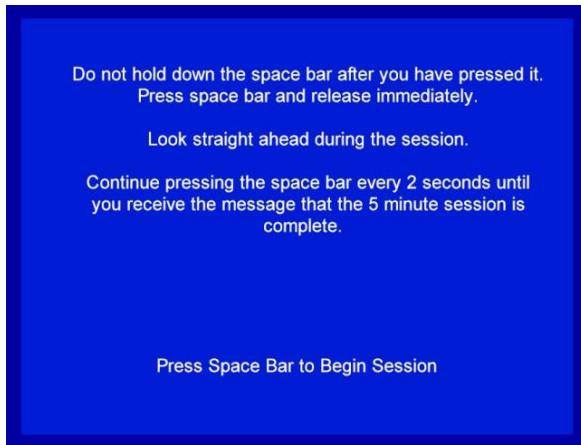


As soon as the user demonstrates that they understand each of the responses, the practice session will terminate and the testing session will begin.

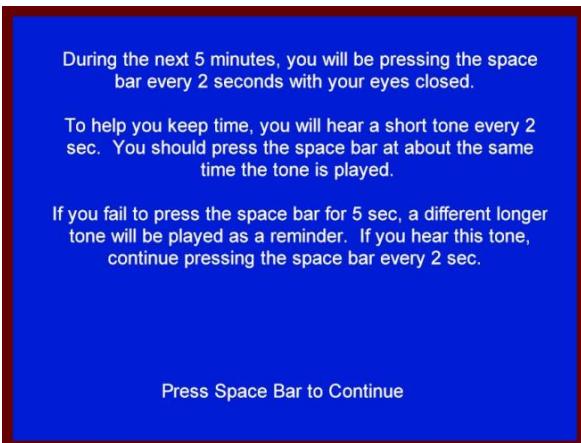
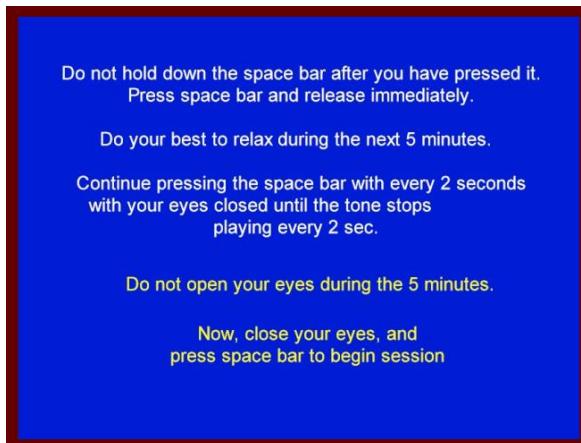


The length of the 3CVT (after the practice period) will depend on the baseline type selected. During the first 5-minute period, stimuli appear frequently and require a high state of alertness. The inter-stimulus intervals are extended in the remaining 15 minutes of the 3CVT in order to better identify 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. VPVT:** The Visual Psychomotor Vigilance Task begins with the following instructions.



**c. APVT:** The Auditory Psychomotor Vigilance Task begins with the following instructions.



After completing the third and final Benchmarking Task, a completion dialogue will appear informing the participant to wait for the technician. The technician must press the F11 key at this time to complete the testbed and initiate the final quality check. See Section 3.4 for more information.



Once acquired, the Benchmarking session files will be stored in the subject's folder. The definition file needed for EEG-based Metrics will also be automatically generated and placed in the subject's folder. The .def file is required to ensure validity and accuracy across each individual subject.

### 3.3 Acquisition Troubleshooting

During any of the three tasks in the Benchmarking sessions, the user may use the following shortcuts

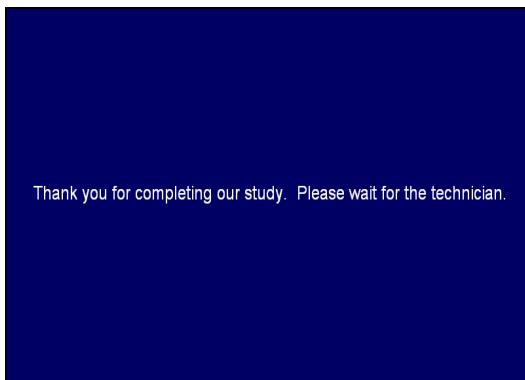
- Ctrl+Alt+Q (**Quit**): Quit the session. For use by the technician.
- Ctrl+Alt+R (**Restart**): Restart the current task. For use by the technician.
- Ctrl+Alt+P (**Pause**): Pause the current task. It is not recommended to pause the task.
- Ctrl+Alt+C (**Continue**): Resume after Pause.
- Ctrl+Alt+J (**Jump**): Skip the current task.
- Ctrl+Alt+V (**Review**): Review previous instructions before the commencement of the task.

**Note:** If the session is terminated prematurely before the completion of all the tasks, use Ctrl+Alt+Q shortcut key to terminate the session in order to save all the outputs to the files. Failure to do so will result in all output data being lost.

### 3.4 Exiting Benchmarking Session

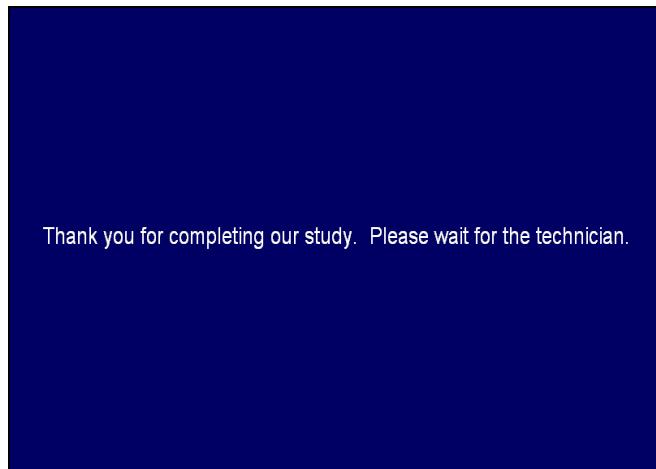
**Function Key F11** - is used to get out of a “Technician Requested” window, when subject is kicked out of a task due to a lack of response, or to exit out of the last screen of the Benchmark.

The following are examples of when to use this button:



## B-Alert Software Manual

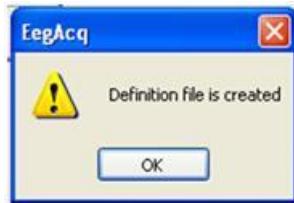
Upon completing the final task, this screen will appear:



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 the Benchmarking session, BLS 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 benchmark file and summary report are generated.



If the definition file and benchmark 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 5**. The dialogue summary (xxxxx\_BenchmarkReport.csv, where xxxxx indicates subject/session ID) will also be created when invoking the action offline.



## B-Alert Software Manual

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, re-running the flagged tasks is recommended 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 BLS identifies an EEG benchmark 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.

The definition file, if created successfully, will be labeled as follows:

xxxx\_by\_MMDDYY\_HHMMSS.def

Where,

- xxxx = subject number
- b9, b15, b30 for short, medium, long session
- MMDDYY = date
- HHMMSS = time

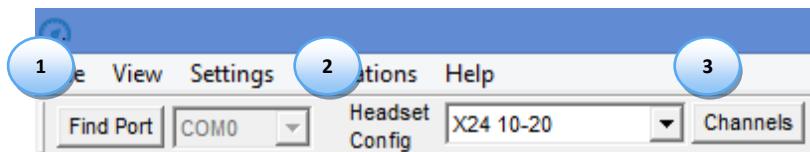
A summary report called "BenchmarkReport.csv" will be created for each session and will provide additional information regarding the quality of the definition file that was created. The sections included in the report are as follows:

- Session Quality
  - Based on Artifacts
  - Based on subjects performance
  - Based on Cognitive State classifications
- Cognitive State Metric classifications for the session
  - Thresholds for three tasks
  - Quality based on the thresholds
- Individual/Population Metrics for each task
  - Quality
  - % classifications (based on epochs)
  - Valid/Total epochs used
  - % artifacts
  - Average of classifications for the entire task
  - Performance parameters (Correct responses, Reaction time, lapses)

## Chapter 4: Advanced Settings and Operations

### 4.1 Taskbar

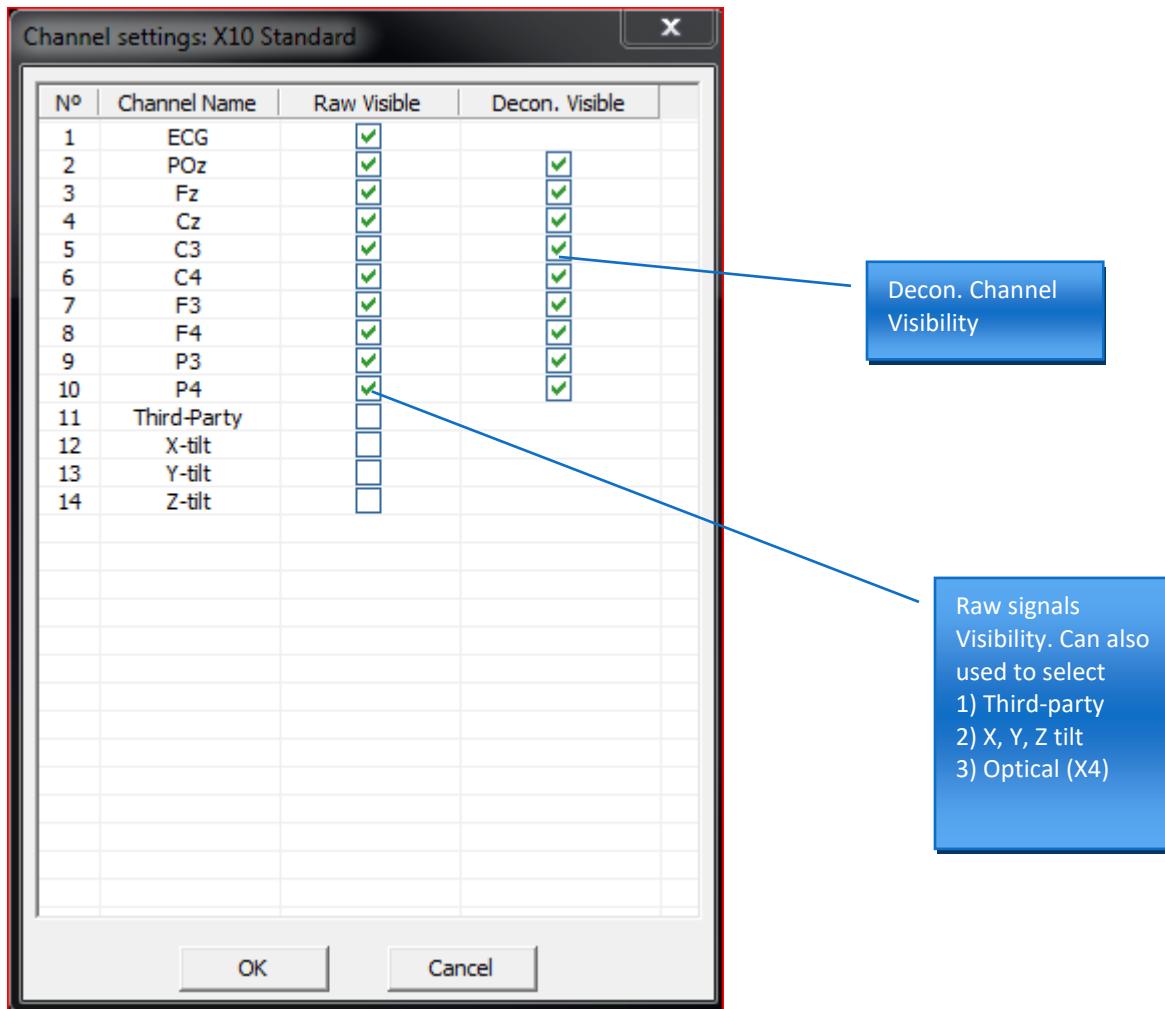
The settings bar can be hidden by deselecting the settings bar option in the view menu. If the settings bar option is selected, the settings toolbar appears as shown.



- Find Port:** Selecting "Find Port" will locate and assign the serial port for communication between the headset and the B-Alert Live Control GUI. Before clicking 'Find Port,' make sure the headset is connected to its corresponding dongle or ESU 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
- Headset Config:** Select type of headset (in most cases this will be automatically selected; when a wrong configuration is selected the user will be notified).

GUI Display Name:	Includes:
X24 10-20	B-Alert X24 with 10-20 sensor strip or Stat X24 with 10-20 sensor strip
X24 Visual	B-Alert X24 with Visual sensor strip or Stat X24 with Visual sensor strip
X10 Standard	B-Alert X10 or Stat X10
X4 Standard	B-Alert X4 or Stat X4
X4 APPT	Reserved for ABM internal testing
X4 Sleep Profiler	Reserved for specialized use

### 3. Channel Map Ellipsis Button: Select channel visibility.

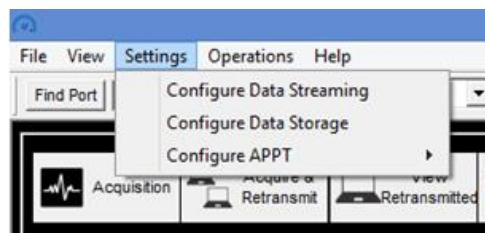


Additional channels that can be selected are as follows:

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

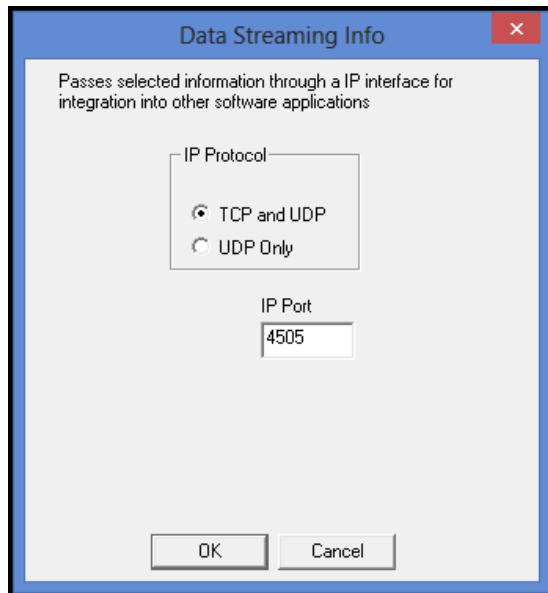
## 4.2 Settings

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



## 1. Configure Data Streaming

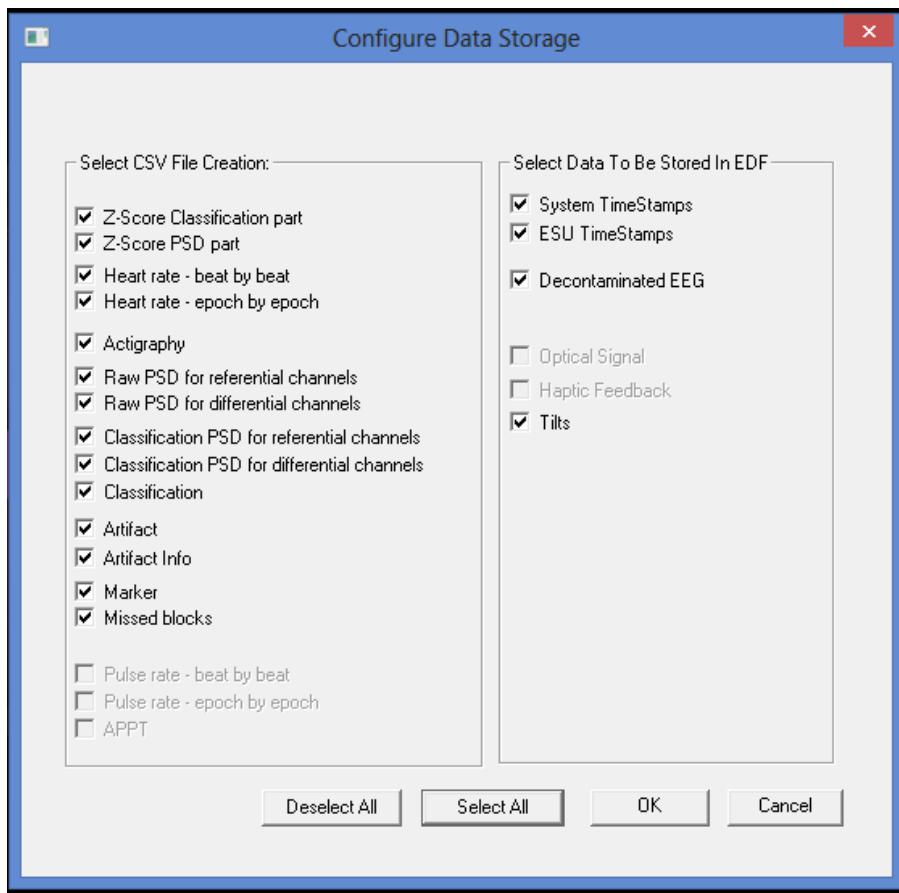
Selecting the Data Streaming option opens the Data Streaming Info window:



- 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:
- c. Time Stamp: Elapsed time for the current session (seconds and milliseconds).
- d. Raw EEG: Raw EEG signal.
- e. Decontaminated EEG: EEG signal after removal of artifacts as identified by ABM decon algorithms.
- f. Artifact: The start and stop times of artifacts identified in the EEG.
- g. Heart Rate: the beat to beat heart rate and heart rate variability.
- h. 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.
- i. Raw PSD: PSDs computed without decontaminating artifacts and without applying Kaiser Windows. The PSDs are still averaged across 3-epoch overlays.
- j. B-Alert Classification: Probabilities of High Engagement, Low Engagement, Distraction, and Sleep Onset (i.e. the Cognitive State Metrics).
- k. Workload Classification: Probability of High Workload.
- l. Head Movement: Accelerometer data.
- m. Third Party Data: Third-party events sent to ABM receiver (ESU).
- n. IP Port: Designates the IP Port that the server opens for all clients to connect.
- o. UDP Only – passes only the Time Stamp data via UDP.

## 2. Configure Data Storage

This option allows users to configure which BLS output files are created during Data Acquisition (in both 'Acquisition' and 'Acquire & Retransmit'). The default setting is to save all output types, but users have the option to deselect outputs as desired.

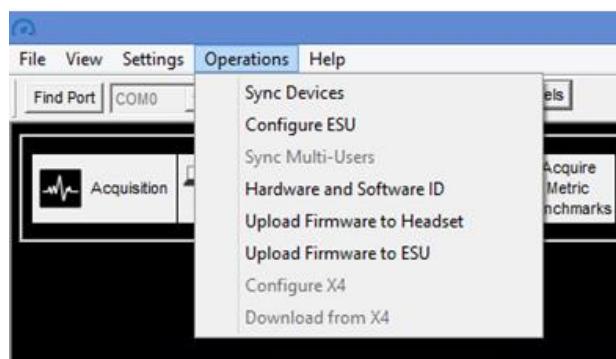


## 3. Configure APPT and Sleep Profiler

Reserved for ABM internal R&D.

### 4.3 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 a Benchmarking Session.



## 1. Sync Devices

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

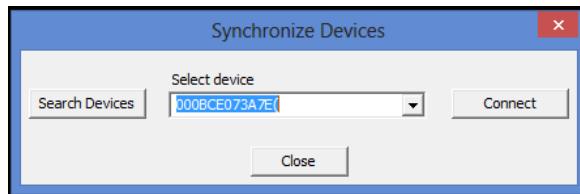
- a. Plug the ESU receiver into your PC. *Note:* Ensure that all nearby B-Alert products, including headsets and ESUs, are turned off and unplugged.



- b. Switch ON the B-Alert headset. Wait until the headset LED pattern is flashing Green 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 XXXXXXXXXXXX). Example: 000BCE042CCA (ABM EEG 300103056):



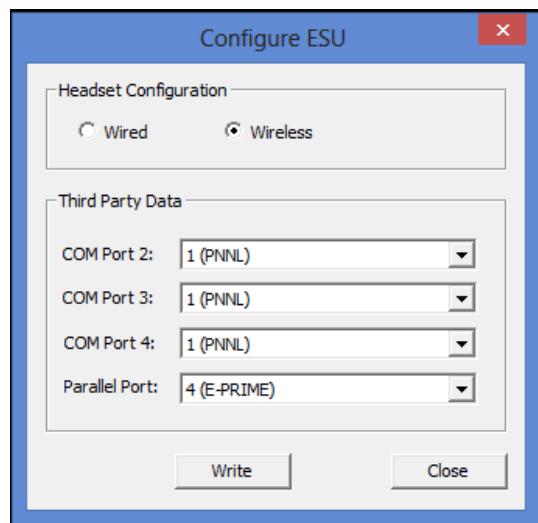
- g. Click "Connect" and wait for the pop-up window indicating that the headset has connected: "Device connection succeeded. Please restart device."



- h. Click 'OK,' then switch OFF the Headset.
- i. Unplug the ESU receiver, and then re-plug it into the laptop/computer.
- j. Switch the headset back ON; wait 5-10 seconds for the Green LED on headset to turn Solid Green, signaling the headset has synced.

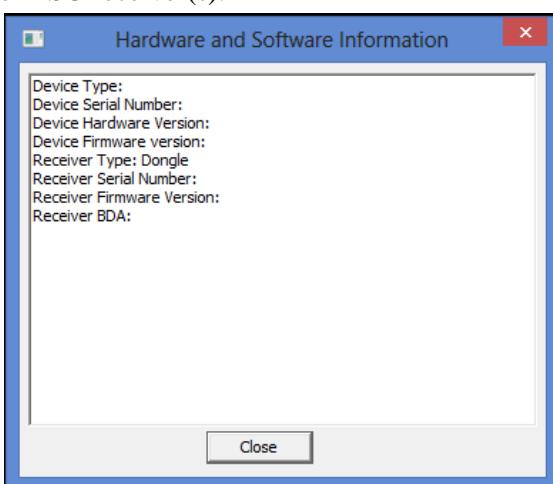
## 2. Configure ESU

Users with the ESU have the option to configure the serial and parallel port settings. Please refer to **Chapter 6** 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 as well as any corresponding USB dongles or ESU receiver(s).

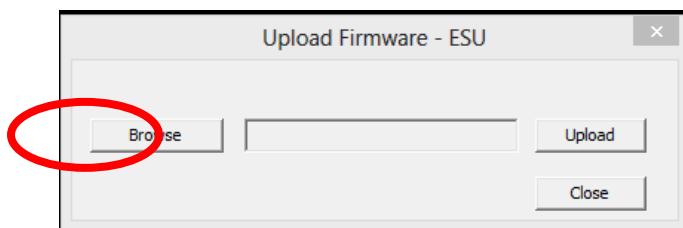


**Note:** The information in this window is valuable for debugging purposes. If possible, please send a snapshot of this window during all hardware-related correspondence with support representatives.

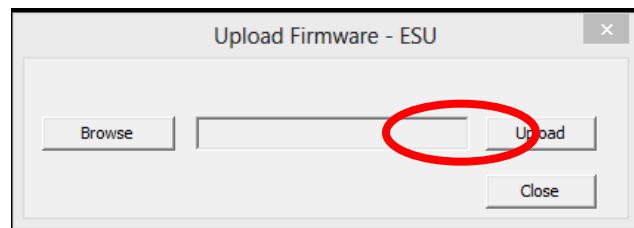
### Upload Firmware to Headset

The "Upload Firmware to Headset" option allows users to update the headset firmware. Please note that a corresponding USB dongle or ESU receiver is required. The procedure is as follows:

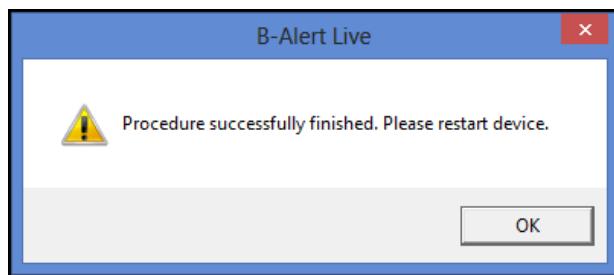
- a. Connect the headset to the dongle or ESU (the solid Green LED confirms connection). Select "Upload Firmware to Headset" from the Operations menu.
- b. Click the 'Browse' button to select path to the firmware .txt file:



- 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:



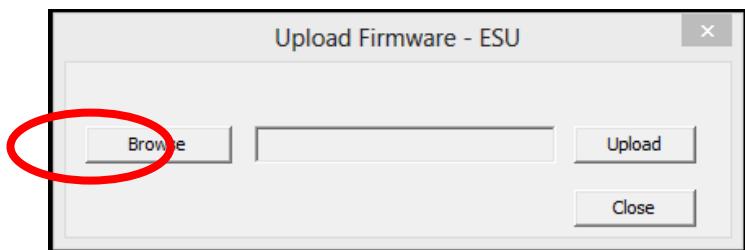
- e. Finalize the firmware upload by restarting the Headset (i.e., switching off/on).

**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.

### 4. Upload Firmware to ESU

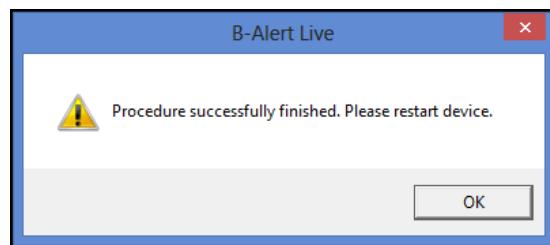
The "Upload Firmware to ESU" option allows users to update firmware on the headset's USB dongle and/or ESU receiver. The procedure is as follows:

- a. Plug in the USB dongle or 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:



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- c. After selecting the 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 ESU receiver (unplugging/re-plugging).

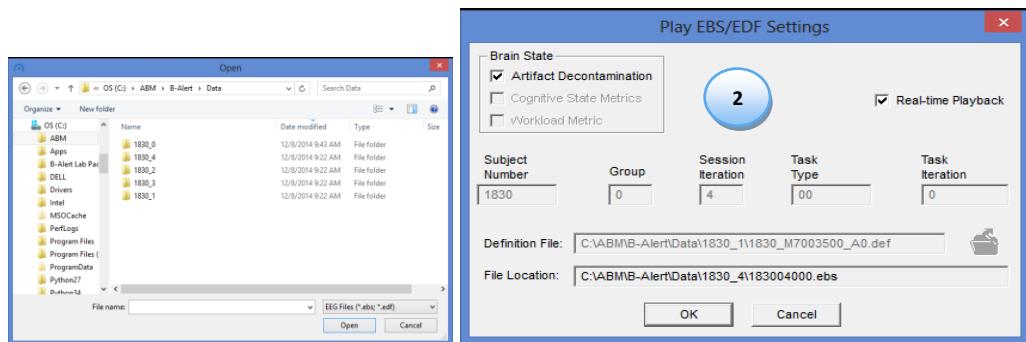
## Chapter 5: Data Analysis and Review

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



### 5.1 Inspect EEG Record

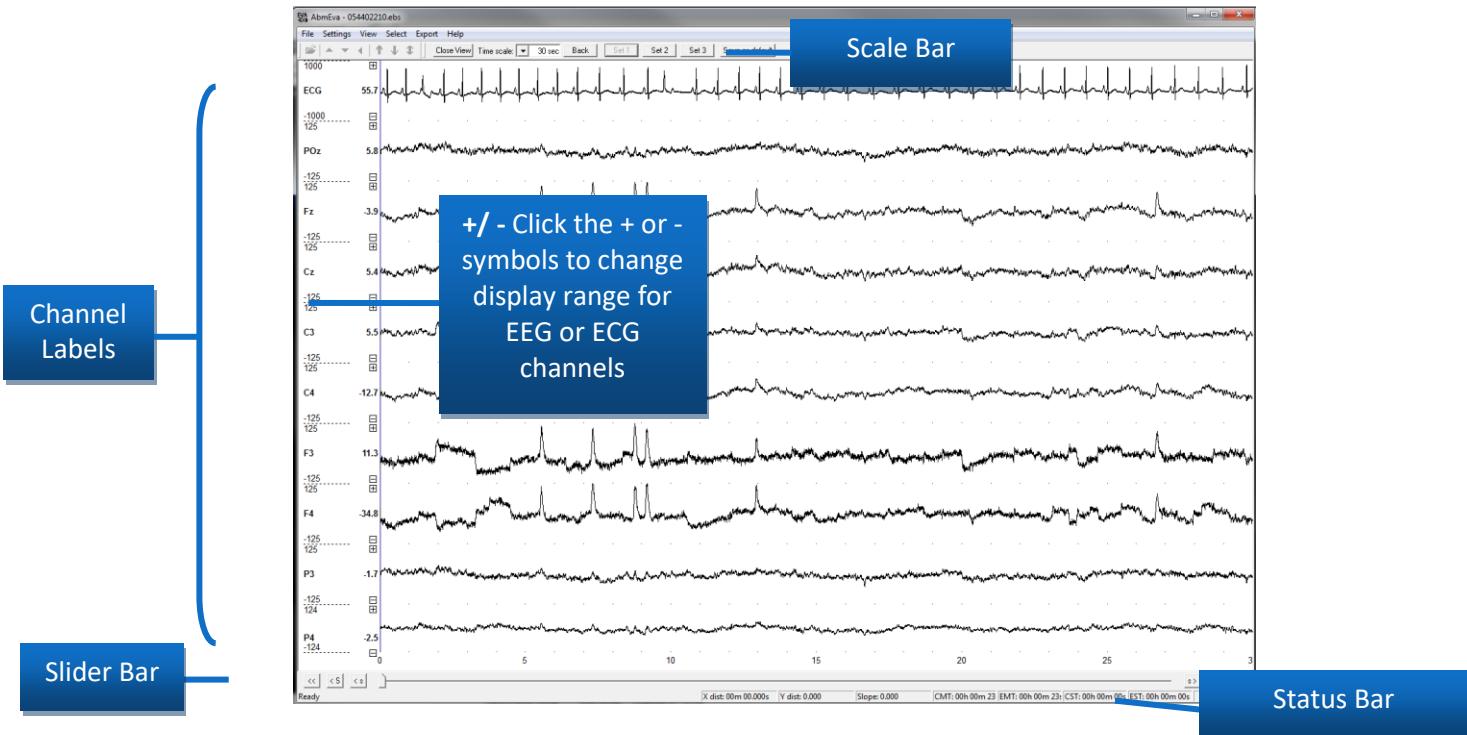
To begin Playback of a previously recorded file, click the "Inspect EEG Record" icon. This will open a browse window. From the browse window, select the desired .EBS (or .EDF) file and click the Open button. The Play EBS Settings dialog will then be presented. Select the playback mode by either checking or un-checking (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 Offline Playback using EVA** for more details.
2. **Brain State:** For Real-Time Playback session, it is optional to select whether the Cognitive State and Workload Metrics classifications are included. **Artifact decontamination is also optional.**
3. **Definition File:** If the subject has a Benchmark 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. This option is only applicable for Real-Time Playback and not for Offline Playback (EVA).

## 5.2 Offline playback using EVA

If 'Real-Time Playback' is left unchecked, the entire data file will be opened using the EVA software (the 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.

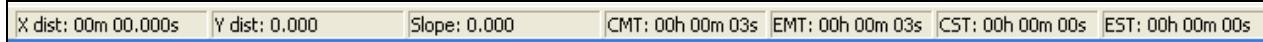


Zoom Down: Change the scaling of the selected channel by zooming out.



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.

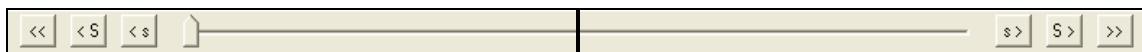
**CMT (Clock Mouse Time):** Allows the user to see a point in time based on the inserted clock time.

**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:

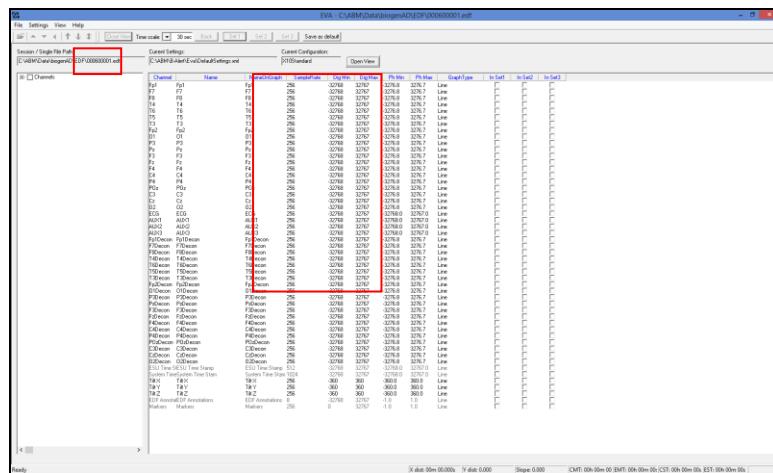
**Time Scale:** Adjusts the time scale for the signals presented on the screen.

**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.

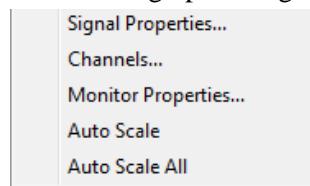
**Save as Default:** If any adjustments are made to the presentation of signals on Sets 1, 2, or 3 and it is desired to keep these settings as the default, use the Save as Default button. The next time EVA is opened, the new default settings will be presented.

**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.



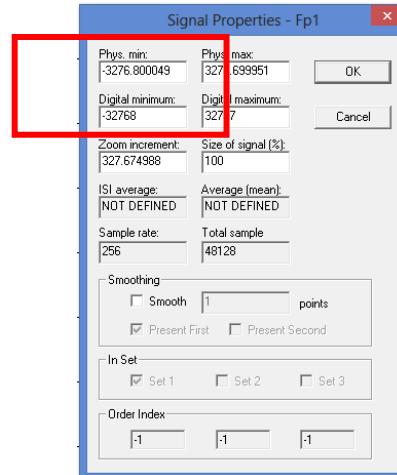
## 5. Right Click Menu:

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



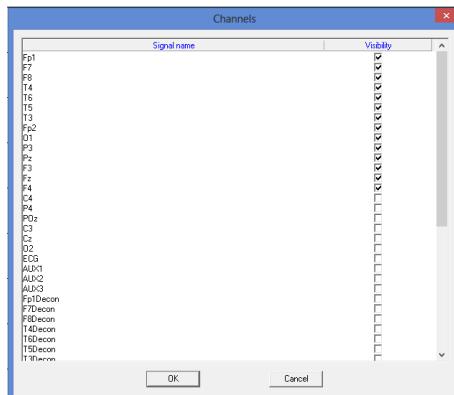
### a. Signal properties:

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



- **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.

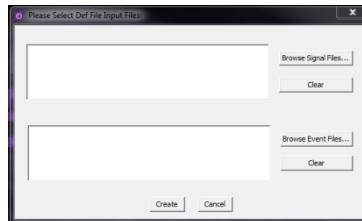


- c. Monitor Properties: allows users to customize the display settings: fonts, colors, and axis properties.
- d. Auto Scale: Adjusts the Channel Y axis range based on Max/Min values for that channel across the entire file.
- e. Auto Scale All: Adjusts the Channel Y axis range based on Max/Min values for each channel in Set 1 across the entire file.

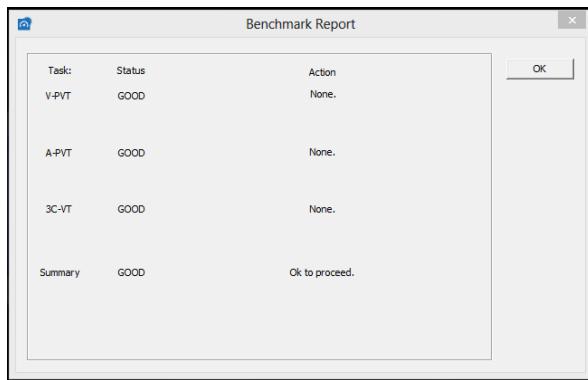
### 5.3 Create Definition File

After completing a Benchmarking session, the definition (.def) file is automatically generated and saved to the subject folder. This .def file is used to generate the Benchmark Report file. If the .def file needs to be recreated, the "Create Definition File" icon can be used. **Note:** Signal .edf and all baseline Events .edf files must be located within the *same* folder, and have the same 9-digit # for a .def file to generate properly. Follow the steps below to create a .def file.

1. Acquire necessary Benchmarking data for that individual subject from each of the three tasks (3CVT; VPVT; APVT).
2. Click the "Create Definition File" icon. The Definition File Settings window will open.



3. Browse Signal Files to locate the \*Signals.Raw.edf file in the session sub-folder for the desired session
4. Browse Event Files to locate the 3file needed: the 3CVT, VPVT, and APVT \*Events.edf files that correspond to the Signal.Raw.edf file previously selected
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 Benchmark task(s). Once created, the individualized .def file can be reused across sessions (for Cognitive State and/or Workload Metric classifications) for a given individual.



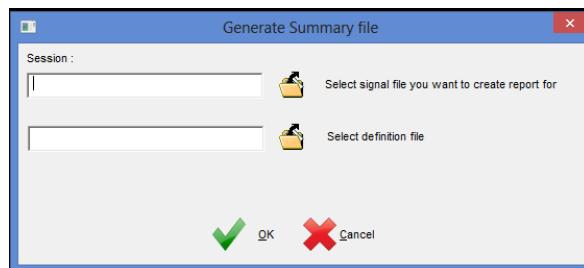
8. Check for the Definition File Report in the folder path to ensure the .def file was created.
9. Note: In case of repeated benchmark, user must input all applicable (up to 3) Signal .edf files, but \*only\* the three correct Events .edf files.
10. For additional consultation regarding definition file validity, please contact your technical support representative.

After completing a Benchmarking session or running the Create Definition file function, the Benchmark Report is automatically generated and saved to the subject folder alongside the .def. The Benchmark Report summarizes performance, classification data, and PSDs (along with heart rate, if available) across the three benchmarking tasks: the 3-Choice Vigilance Task (3-CVT; \*.Events.edf), Visual Psychomotor Vigilance Task (VPVT; \*.Events.edf), and Auditory Psychomotor Vigilance Task (APVT; \*.Events.edf). A Benchmark 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 Benchmark Report, for each of the three tasks.

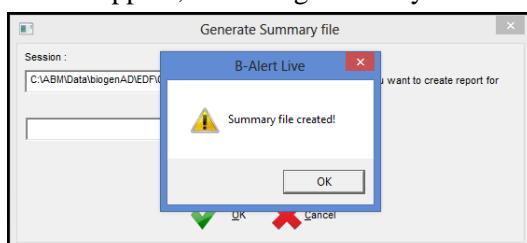
## 5.4 Generate Summary File

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:



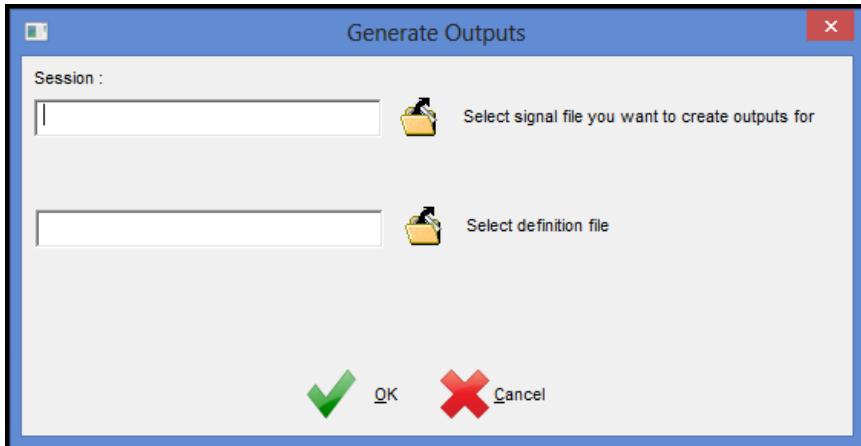
3. Browse to and select the desired .ebs file. The .def file must be placed alongside the .ebs file to generate reports.
4. Click OK.
  - Wait for the Pop-Up window to appear, indicating summary file has completed:



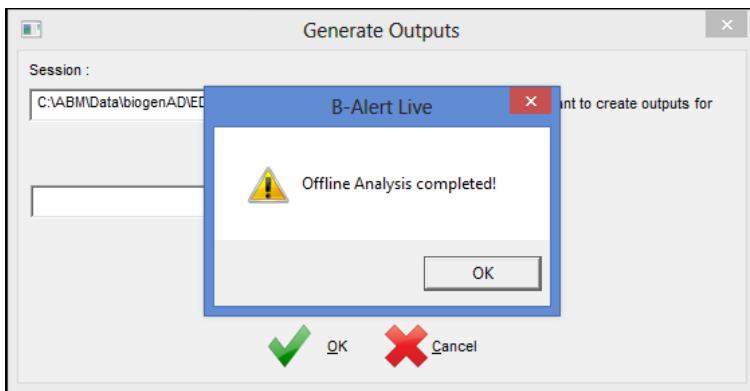
5. Summary.csv will be created with the following contents:
  - a. 30 second averages of HR
  - b. 30 second averages of bandwidths
  - c. 30 second averages of classifications (if definition file is selected)

## 5.5 Offline Analysis

1. Click on the “Offline Analysis” icon. The Generate Outputs window will open:



2. Browse to and select the desired .edf or .ebs file. The .def file can be placed alongside the .ebs/.edf file to generate outputs.
3. Wait for the pop-up window to appear, indicating offline analysis has completed:

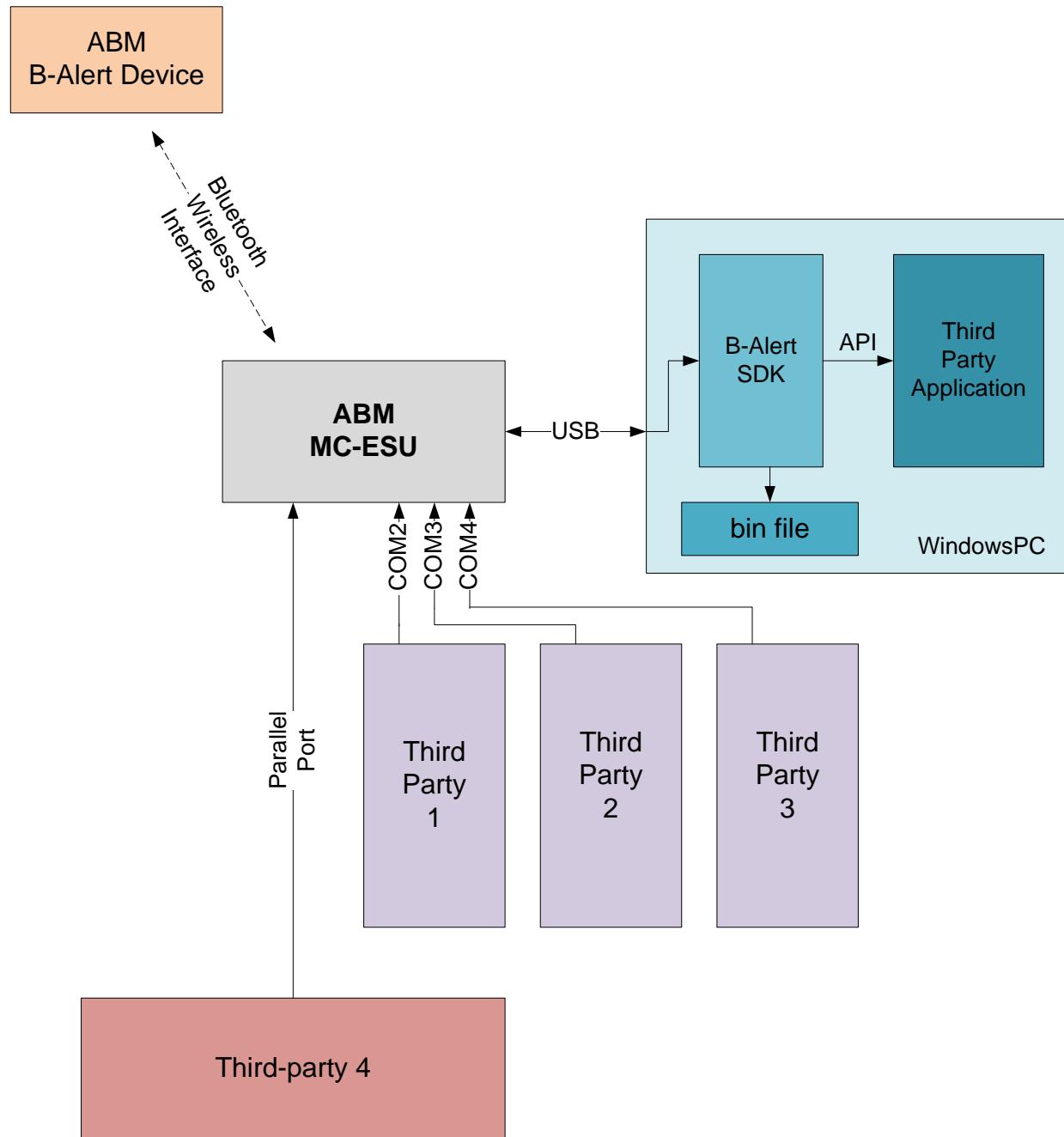


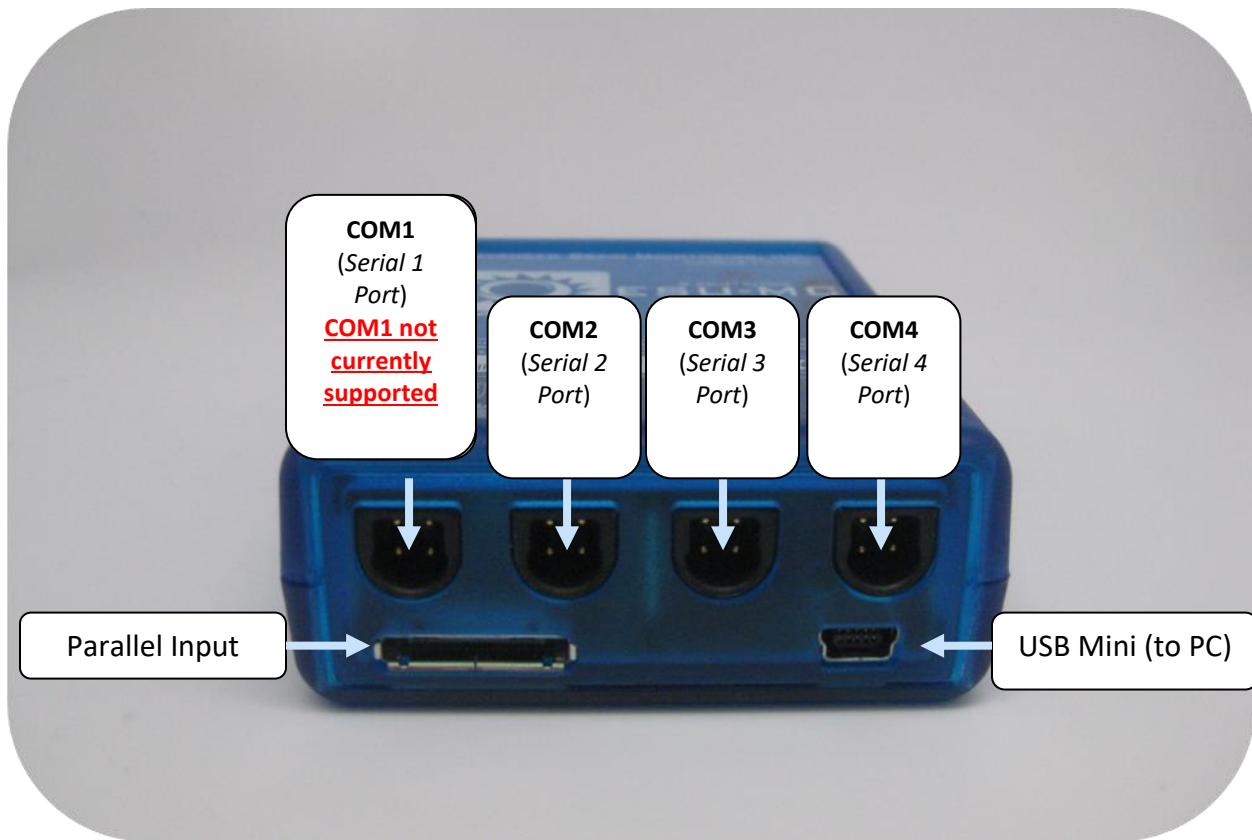
4. The following files can be generated using offline analysis
  - a. HR\_beat.csv : Beat by Beat detection and computation of Heart Rate
  - b. HR\_epoch.csv: Epoch by epoch detection of heart rate
  - c. Diff\_class.csv : Decontaminated differential channel PSD
  - d. Diff\_raw.csv: raw differential channel PSD
  - e. Ref\_class.csv : Decontaminated referential channel PSD
  - f. Ref\_raw.csv : raw referential channel PSD

**Note:** For comprehensive processing of data, ABM offers standalone offline processing software called **B-Alert Lab**. Please contact customer support for more information.

## Chapter 6: External Sync Unit (ESU)

### 6.1 General ESU Information





The External Syncing Unit (ESU) can be used to timestamp data from both 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 ESU thus eliminates Windows-related variable delay by time stamping data packets externally.

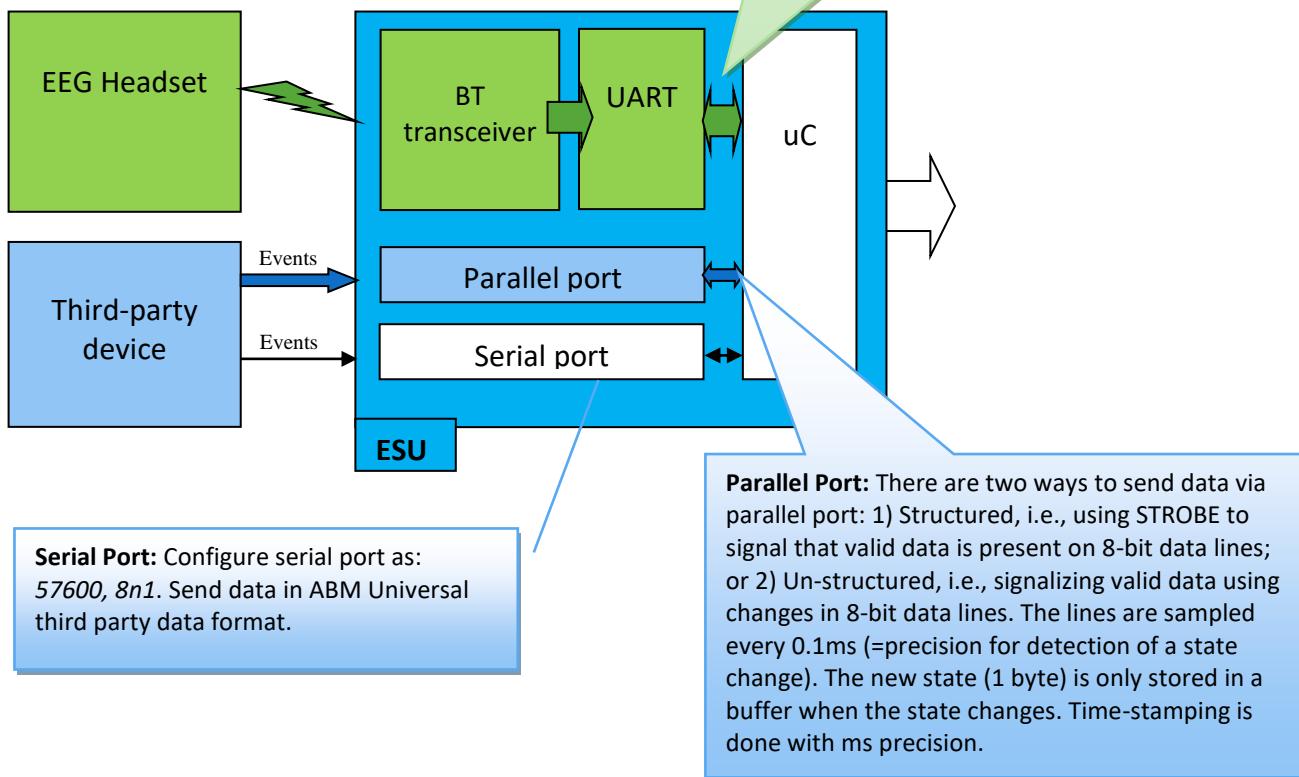
The ESU also functions as a Bluetooth receiver for ABM devices, and it has the ability to decode ABM protocol and stream the data to the SDK via the USB port (i.e., the USB port registers a Virtual COM port in the PC). B-Alert X10 and X4 devices bundle two samples from each acquired signal into a single packet that gets time stamped every 8 msec, while the X24 sends only one sample and is time stamped every 4 msec. COM1 is currently not supported for connections, 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 ESU, however, in the event of conflict, EEG packets will have priority over other data. Proprietary cables supplied with the 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 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

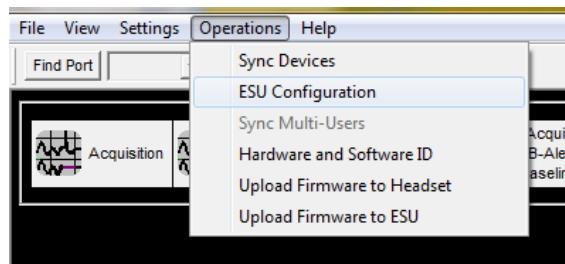
Cable Name	Photo
USB Cord (connect ESU to PC)	 A blue rectangular electronic device with a black USB cable attached. The device has a small screen and several buttons. The word "ESU-MC" is printed on it.
Serial Port to ESU cable	 A black cable with a DB-9 female connector on one end and a smaller connector on the other.
Parallel to ESU Cable	 A white cable with a DB-25 male connector on one end and a smaller connector on the other.

## 6.2 ESU Block Diagram

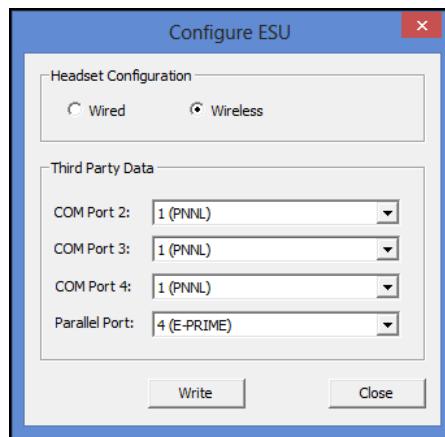


### 6.3 Configuring the ESU Settings

1. Plug in the ESU into USB port on a computer.
2. Open B-Alert Live Control GUI:



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

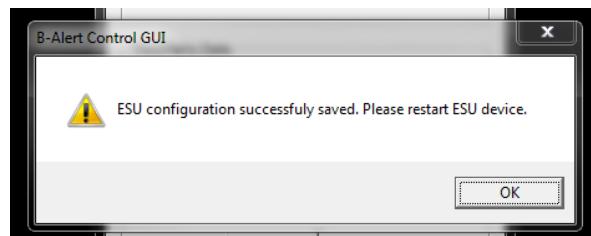


4. Use the drop down menus to configure ESU Third Party Data (3 Serial Ports and 1 Parallel Port) as desired. See Section 6.4 Third Party Data Format (below) for the specifications for the different T-Party settings.

**Warning:**

Do NOT use the port labeled COM1 in the ESU for sending events from third-party interfaces. COM1 is currently not supported.

5. Click the 'Write' Button to write settings changes to the ESU.
6. Wait. A pop-up window will appear to confirm the configuration was saved. Restart the ESU by unplugging it and then re-plugging it into the computer's USB.



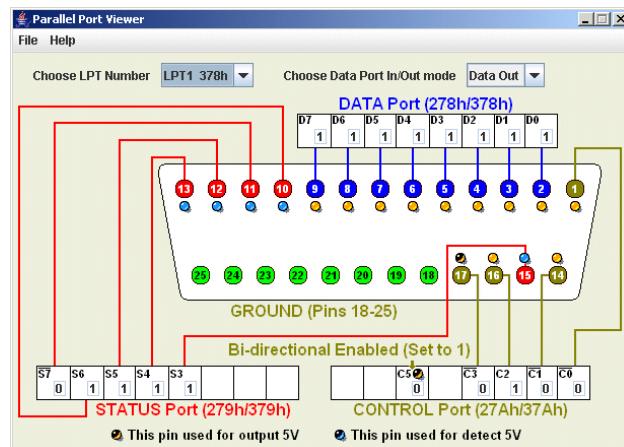
## 6.4 Third Party Protocols and Packet Structure

The 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 uses 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 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 =  $255 - \text{Mod}(\text{SumOfAllBytes(Packet Length, PTY, DATA)}, 256)$

**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

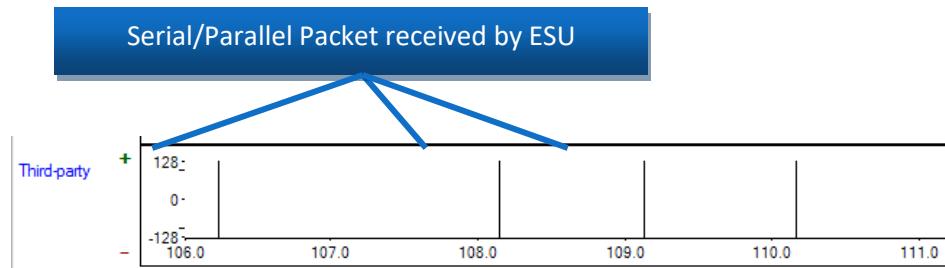
B-Alert Live Software unpacks the data received from the ESU and stores it in a bin file, or an events edf+ file. The events packet has the following structure for each event:

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 =  $\text{BYTE1} \times 2^{24} + \text{BYTE2} \times 2^{16} + \text{BYTE3} \times 2^8 + \text{BYTE4} \times 2^0$  )
- Packet Length: equal to the number of bytes in User Data field
- Packet Type: protocol used
- User Data
- Checksum:  $\text{Mod}(\text{SumOfAllBytes(Packet Length, PTY, DATA)}, 256)$

## 6.5 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 4: Advanced Settings and Operations*). 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 strobos in this line:



**Note:** These strobos 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

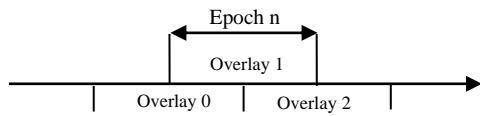
### A.1 Overview

The B-Alert Live Software (BLS) allows users to utilize patented and peer-review validated EEG-based Metrics, Automatic Decontamination, PSD, and ECG algorithms if desired. These data outputs are either created in real time (See Real-Time Data Outputs Overview Table below) or offline. Below is an overview of some of the methods and techniques used by BLS to compute its various measures.

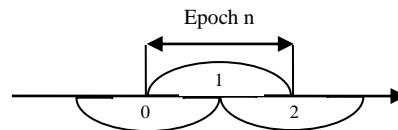
- 1. Computing Power Spectral Densities:** Power spectral density (PSD) is computed by performing Fast Fourier Transform (FFT) on a segment of data that is of interest, and calculating the amplitudes of the sinusoidal components for designated frequency bins. Input variables to this transformation are 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 – 13 Hz, etc.). 'Diff\_' files contain data for Differential EEG channels used for the Cognitive State Metric classifications (FzPOz, CzPO, FzC3, C3C4, and F3Cz). 'Ref\_' files contain PSD values for 9 referential EEG channels (POz, Fz, Cz, C3, C4, F3, F4, P3, and 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

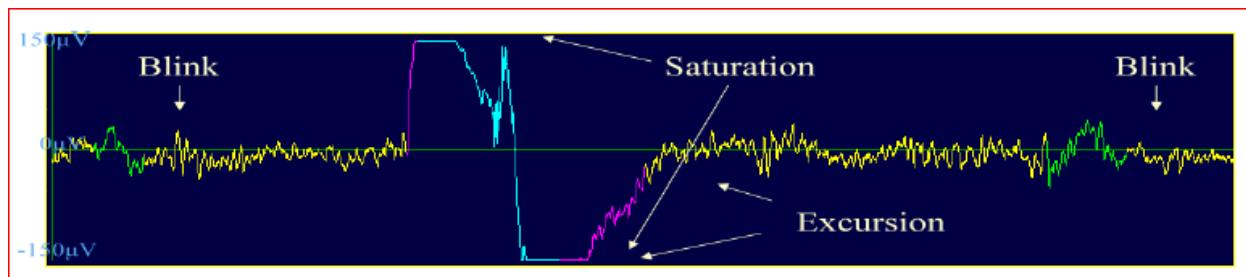


50% Overlap – Ref\_Class, Diff\_Class  
(Kaiser windowing applied)



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 gamma frequency ranges. Eye blinks (EOG) occur in the same frequency range as theta activity.

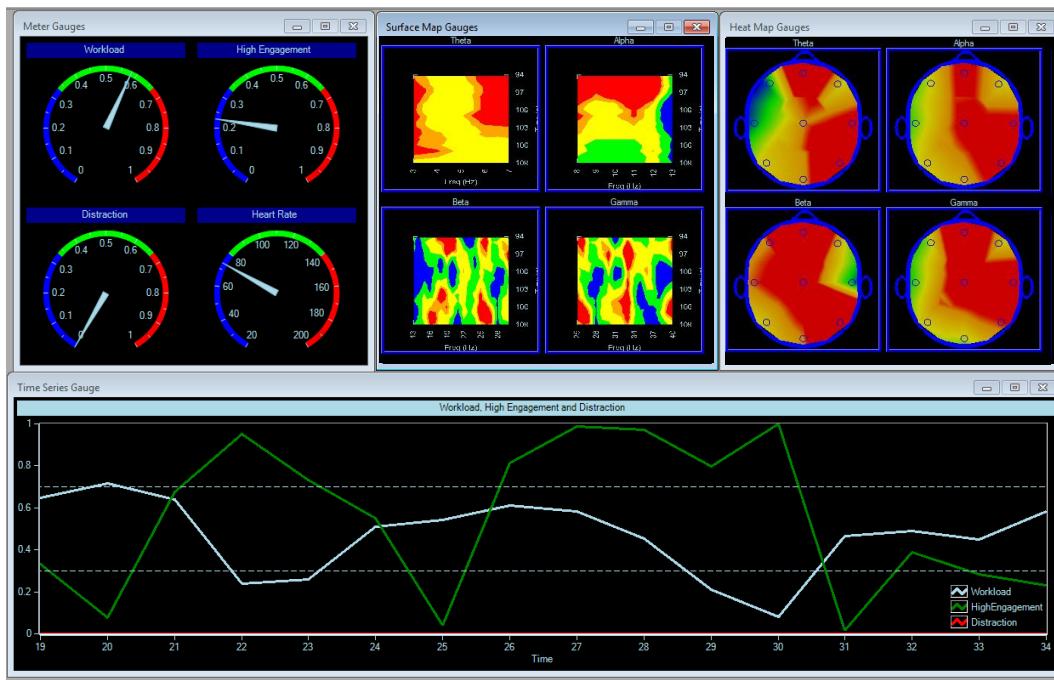
**Before Decontamination:****After Decontamination:**

- 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 (EOG) – 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 the Cognitive State And Workload Models:



The EEG-based Metrics are normalized to an individual subject using 5-7 min of baseline data from three distinct tasks (3CVT, VPVT, and APVT), with the sleep onset classification 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). The 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.

Benchmark Task	Action	B-Alert Class probabilities
<b>3CVT</b>	Discriminate between primary vs. secondary or tertiary stimulus every 1.5 to 3 seconds	High Engagement
<b>VPVT</b>	Respond to visual probe every 2 seconds	Low Engagement
<b>APVT</b>	Respond to audio tone every 2 seconds	Distraction
<b>None</b>	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 Cognitive State Metric probabilities for each individual should be interpreted in a relative, rather than absolute, manner. Three standardized benchmarking tasks normalize the metrics to each individual. High population variability for EEG activity requires individualized model fitting, which is done for each 1Hz 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 the benchmarking tasks. If a participant is mentally balancing their checkbook during the APVT 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 benchmarking 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 consuming excessive caffeine or nicotine immediately prior to conducting their Benchmarking Tasks data; and the session should occur in the morning (8am-10am) after a full night of sleep to collect an optimal session.

The Cognitive 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 Cognitive State 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 are 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 Live software share common formatting features. For example, all file names begin with the nine digit subject/session number (XXXXXXXXXX), followed by a 6 digit date (YYYYYY), followed by a 6 digit timestamp(ZZZZZZ), 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
<b>Data file</b>	
Xxxxxxxxxx.yyyyyy.zzzzzz.ebs	Proprietary Extensible bio-signal file format. Stores raw data with identical sampling such as EEG and EKG.
Xxxxxxxxxx.yyyyyy.zzzzzz.Signals.Raw.edf	European data format containing raw data with variable sampling such as EEG, EKG, Accelerometer data, Marker etc. The EDF file is compatible with most third party viewers. Some channels in EDF file are selectable (see <b>Chapter 4: Advanced Settings and Operations</b> ).
Xxxxxxxxxx.yyyyyy.zzzzzz.Decon.edf	Decontaminated data from Signas.Raw.edf
Xxxxxxxxxx.yyyyyy.zzzzzz_Events.edf	Events generated by the ESU stored in EDF+ annotation format.
Xxxxxxxxxx.yyyyyy.zzzzzz.Impedance.Results.csv	Lists the values obtained for each channel each time impedance was measured.
<b>Automatically Generated during Acquisition – for all EEG Channels</b>	
Xxxxxxxxxx.yyyyyy.zzzzzz.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)

Xxxxxxxxxx.yyyyyy.zzzzzRef_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)
<b>Automatically Generated during Acquisition – Derived Signals</b>	
Xxxxxxxxxx.yyyyyy.zzzzz.HR_beat.csv	Presentation of heart rate based on beat-to-beat interval
Xxxxxxxxxx.yyyyyy.zzzzz.HR_epoch.csv	Beat-to-beat heart rate interpolated to sec-by-sec value
<b>Optionally Generated with Cognitive State Metrics</b>	
Xxxxxxxxxx.yyyyyy.zzzzz.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.
Xxxxxxxxxx.yyyyyy.zzzzz.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).
Xxxxxxxxxx.yyyyyy.zzzzz.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).
Xxxxxxxxxx.yyyyyy.zzzzz.Zscore.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for both the Cognitive State (sleep onset, distraction, low and high engagement) and Workload Metrics (three workload measures).
Xxxxxxxxxx.yyyyyy.zzzzz.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.
<b>Other files</b>	
Xxxxxxxxxx.yyyyyy.zzzzz.Actigraphy.csv	Contains raw tilt values from accelerometer and derived movement values/scales.
Xxxxxxxxxx.yyyyyy.zzzzz.Artifact.csv	Contains detected artifacts and their start/end markers.
Xxxxxxxxxx.yyyyyy.zzzzz.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.
Xxxxxxxxxx.yyyyyy.zzzzz.thirdparty.bin	Stores third-party packets sent to the ESU (only for ESU).
Xxxxxxxxxx.yyyyyy.zzzzz.optical.bin	Stores IRED data from the headset (only for X4).
Xxxxxxxxxx.yyyyyy.zzzzz.accelerometer.csv	Stores raw accelerometer data in bin format.

**Note:** The files created during acquisition depend on the selection in "Configure Data Storage" setting (see *Chapter 4: Advanced Settings and Operations*). It also depends on the type of processing selected (Artifact Decontamination), EEG-based Metrics (Cognitive State and Workload classifications), and type of the device used (X4, X10, X24).

## A.1 EEG-based Metrics including Cognitive State & Workload Outputs

### 1. Classification.csv

Classification.csv shows the second by second (epoch by epoch) data outputs for ABM's two EEG models: (1) 4-Class Cognitive State Metric model of drowsiness: (Sleep Onset, Distraction, Low Engagement, High Engagement); and 2-Class model of Workload (High Workload, Low Workload). These outputs will *only* be generated if the user has checked either of the 'Brain State' check boxes (Cognitive State Metrics 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)

<b>C</b>	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
<b>D</b>	fzpoz_1	PSD power at channel FzPoz (with Kaiser windowing) for the 1 Hz bin
<b>E</b>	fzpoz_2	PSD power at channel FzPoz (with Kaiser windowing) for the 2 Hz bin
<b>F - AQ</b>	fzpoz_3-40	PSD power at channel FzPoz (with Kaiser windowing) for the 3-40 Hz bins
<b>AR</b>	fzpoz_rel1	<i>Relative</i> PSD power at channel FzPoz (with Kaiser windowing) for 1 Hz Bin
<b>AS - CE</b>	fzpoz_rel2-rel40	<i>Relative</i> PSD power at channel FzPoz (with Kaiser windowing) for 2-40 Hz Bin
<b>CF</b>	fzpoz_Delta_1_2	PSD for Delta Bandwidth at channel FzPoz (not relative PSD) summed from Hz bins 1-2
<b>CG</b>	fzpoz_ThetaSlow_3_5	PSD for Theta-Slow Bandwidth (not relative PSD) summed from Hz bins 3-5
<b>CH</b>	fzpoz_ThetaFast_5_7	PSD for Theta-Fast Bandwidth (not relative PSD) summed from Hz bins 5-7
<b>CI</b>	fzpoz_ThetaTotal_3_7	PSD for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7
<b>CJ</b>	fzpoz_AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth (not relative PSD) summed from Hz bins 8-10
<b>CK</b>	fzpoz_AlphaFast_10_13	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 10-13
<b>CL</b>	fzpoz_AlphaTotal_8_13	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 8-13
<b>CM</b>	fzpoz_Gamma_25_40	PSD for Gamma Bandwidth (not relative PSD) summed from Hz bins 12-15
<b>CN</b>	fzpoz_Beta_13_29	PSD for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29
<b>CO</b>	czpoz_1	PSD power at channel CzPOz (with Kaiser windowing) for the 1 Hz bin
<b>CP - QF</b>		PSD/Relative PSD information for all differential channels (CzPOz, FzC3, C3C4, F3Cz uses the same naming convention as FzPOz, described above)
<b>QG</b>	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
<b>QH</b>	AlphaOverall_8_13	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-13
<b>QI</b>	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
<b>QJ</b>	GammaOverall_25_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
<b>A</b>	SessionNum	Session Name (.ebs File Name)
<b>B</b>	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
<b>C</b>	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
<b>D</b>	fzpoz_1	PSD power at channel FzPoz (without Kaiser windowing) for the 1 Hz bin
<b>E</b>	fzpoz_2	PSD power at channel FzPoz (without Kaiser windowing) for the 2 Hz bin
<b>F - AQ</b>	fzpoz_3-40	PSD power at channel FzPoz (without Kaiser windowing) for the 3-40 Hz bins
<b>AR</b>	fzpoz_rel1	<i>Relative</i> PSD power at channel FzPoz (without Kaiser windowing) for 1 Hz Bin
<b>AS - CE</b>	fzpoz_rel2-rel40	<i>Relative</i> PSD power at channel FzPoz (without Kaiser windowing) for 2-40 Hz Bin
<b>CF</b>	fzpoz_Delta_1_2	PSD for Delta Bandwidth at channel FzPoz (not relative PSD) summed from Hz bins 1-2 (without Kaiser windowing)
<b>CG</b>	fzpoz_ThetaSlow_3_5	PSD for Theta-Slow Bandwidth (not relative PSD) summed from Hz bins 3-5 (without Kaiser windowing)
<b>CH</b>	fzpoz_ThetaFast_5_7	PSD for Theta-Fast Bandwidth (not relative PSD) summed from Hz bins 5-7 (without Kaiser windowing)
<b>CI</b>	fzpoz_ThetaTotal_3_7	PSD for Theta-Total Bandwidth (not relative PSD) summed from Hz bins 3-7 (without Kaiser windowing)
<b>CJ</b>	fzpoz_AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth (not relative PSD) summed from Hz bins 8-10 (without Kaiser windowing)
<b>CK</b>	fzpoz_AlphaFast_10_13	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 10-13 (without Kaiser windowing)
<b>CL</b>	fzpoz_AlphaTotal_8_13	PSD for Alpha-Fast Bandwidth (not relative PSD) summed from Hz bins 8-13 (without Kaiser windowing)
<b>CM</b>	fzpoz_Gamma_25_40	PSD for Gamma Bandwidth (not relative PSD) summed from Hz bins 25-40 (without Kaiser windowing)
<b>CN</b>	fzpoz_Beta_13_29	PSD for Beta Bandwidth (not relative PSD) summed from Hz bins 13-29 (without Kaiser windowing)
<b>CO</b>	czpoz_1	PSD power at channel CzPOz (with Kaiser windowing) for the 1 Hz bin (without Kaiser windowing)
<b>CP - QF</b>		PSD/Relative PSD information for all differential channels (CzPOz, FzC3, C3C4, F3Cz) uses the same naming convention as FzPOz (described above)
<b>QG</b>	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)
<b>QH</b>	AlphaOverall_8_13	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Alpha Bandwidth (not relative PSD) summed from Hz bins 8-13 (without Kaiser windowing)

<b>QI</b>	GammaOverall_2_5_40	PSD Across ALL 5 differential channels (FzPoz, CzPoz, FzC3, C3C4, F3Cz) for Beta Bandwidth (not relative PSD) summed from Hz bins 25-40 (without Kaiser windowing)
<b>QJ</b>	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)

### 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
<b>A</b>	SessionNum	Session Name (.ebs File Name)
<b>B</b>	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
<b>C</b>	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
<b>D</b>	POz_1	PSD power at channel POz (with Kaiser windowing) for the 1 Hz bin
<b>E</b>	POz_2	PSD power at channel POz (with Kaiser windowing) for the 2 Hz bin
<b>F - AQ</b>	POz_3-40	PSD power at channel POz (with Kaiser windowing) for the 3-40 Hz bins
<b>AR</b>	POz_rel1	<i>Relative</i> PSD power at channel POz (with Kaiser windowing) for 1 Hz Bin
<b>AS - CE</b>	POz_rel2-rel40	<i>Relative</i> PSD power at channel POz (with Kaiser windowing) for 2-40 Hz Bin
<b>CF</b>	POz_Delta_1_2	PSD for Delta Bandwidth at channel POz (not relative PSD) summed from Hz bins 1-2 (with Kaiser windowing)
<b>CG</b>	POz_ThetaSlow_3_5	PSD for Theta-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-5 (with Kaiser windowing)
<b>CH</b>	POz_ThetaFast_5_7	PSD for Theta-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 5-7 (with Kaiser windowing)
<b>CI</b>	POz_ThetaTotal_3_7	PSD for Theta-Total Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-7 (with Kaiser windowing)
<b>CJ</b>	POz_AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-10 (with Kaiser windowing)
<b>CK</b>	POz_AlphaFast_10_13	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 10-13 (with Kaiser windowing)
<b>CL</b>	POz_AlphaTotal_8_13	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-13 (with Kaiser windowing)
<b>CM</b>	POz_Gamma_25_40	PSD for Gamma Bandwidth at channel POz (not relative PSD) summed from Hz bins 25-40 (with Kaiser windowing)
<b>CN</b>	POz_Beta_13_29	PSD for Beta Bandwidth at channel POz (not relative PSD) summed from Hz bins 13-29 (with Kaiser windowing)
<b>CO</b>	Fz_1	PSD power at channel Fz (with Kaiser windowing) for the 1 Hz bin (with Kaiser windowing)
<b>CP - ADX</b>		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)

<b>ADY</b>	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)
<b>ADZ</b>	AlphaOverall_8_13	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 8-13 (with Kaiser windowing)
<b>AEA</b>	GammaOverall_25_40	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Gamma Bandwidth (not relative PSD) summed from Hz bins 25-40 (with Kaiser windowing)
<b>AEB</b>	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)

#### 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
<b>A</b>	SessionNum	Session Name (.ebs File Name)
<b>B</b>	Elapsed Time	Total Elapsed Time for session in seconds (hh:mm:ss:ms)
<b>C</b>	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
<b>D</b>	POz_1	PSD power at channel POz (without Kaiser windowing) for the 1 Hz bin
<b>E</b>	POz_2	PSD power at channel POz (without Kaiser windowing) for the 2 Hz bin
<b>F - AQ</b>	POz_3-40	PSD power at channel POz (without Kaiser windowing) for the 3-40 Hz bins
<b>AR</b>	POz_rel1	<i>Relative</i> PSD power at channel POz (without Kaiser windowing) for 1 Hz Bin
<b>AS - CE</b>	POz_rel2-rel40	<i>Relative</i> PSD power at channel POz (with Kaiser windowing) for 2-40 Hz Bin
<b>CF</b>	POz_Delta_1_2	PSD for Delta Bandwidth at channel POz (not relative PSD) summed from Hz bins 1-2 (without Kaiser windowing)
<b>CG</b>	POz_ThetaSlow_3_5	PSD for Theta-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-5 (without Kaiser windowing)
<b>CH</b>	POz_ThetaFast_5_7	PSD for Theta-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 5-7 (without Kaiser windowing)
<b>CI</b>	POz_ThetaTotal_3_7	PSD for Theta-Total Bandwidth at channel POz (not relative PSD) summed from Hz bins 3-7 (without Kaiser windowing)
<b>CJ</b>	POz_AlphaSlow_8_10	PSD for Alpha-Slow Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-10 (without Kaiser windowing)
<b>CK</b>	POz_AlphaFast_10_13	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 10-13 (without Kaiser windowing)
<b>CL</b>	POz_AlphaTotal_8_13	PSD for Alpha-Fast Bandwidth at channel POz (not relative PSD) summed from Hz bins 8-13 (without Kaiser windowing)
<b>CM</b>	POz_Gamma_25_40	PSD for Gamma Bandwidth at channel POz (not relative PSD) summed from Hz bins 25-40 (without Kaiser windowing)
<b>CN</b>	POz_Beta_13_29	PSD for Beta Bandwidth at channel POz (not relative PSD)

		summed from Hz bins 13-29 (without Kaiser windowing)
<b>CO</b>	Fz_1	PSD power at channel Fz (without Kaiser windowing) for the 1 Hz bin
<b>CP - ADX</b>		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)
<b>ADY</b>	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)
<b>ADZ</b>	AlphaOverall_8_13	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 8-13 (without Kaiser windowing)
<b>AEA</b>	GammaOverall_25_40	Mean PSD across ALL 9 referential channels (POz, Fz, Cz, C3, C4, F3, F4, P3, P4) for Gamma Bandwidth (not relative PSD) summed from Hz bins 25-40 (without Kaiser windowing)
<b>AEB</b>	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)

## A.4 Heart Rate Outputs

\_HR\_beat.csv

\_HR\_epoch.csv

Signal processing performs 5 operations on the raw 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
<b>A</b>	SessionNum	Session Name (.ebs File Name)
<b>B</b>	Elapsed Time	Elapsed time (hh:mm:ss:ms)
<b>C</b>	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
<b>D</b>	Beat Quality	1 or 0 value: 0 = beat quality good, 1 = beat quality poor based on artifact in ECG channel.
<b>E</b>	Inter-Beat Interval	Inter-beat Interval.
<b>F</b>	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 B-Alert Live's Heart Rate algorithm.

Column	Column Name	Description
<b>A</b>	SessionNum	Session Name (.ebs File Name)
<b>B</b>	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)
<b>C</b>	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)

<b>D</b>	Beat Quality	1 or 0 value: 0 = beat quality good, 1 = beat quality poor based on artifact in ECG channel.
<b>E</b>	Inter-Beat Interval	Inter-beat Interval: Interpreted to the second
<b>F</b>	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
<b>A</b>	SessionNum	Session Name (.ebs File Name)
<b>B</b>	Elapsed Time	Elapsed time for the detected beat (hh:mm:ss:ms)
<b>C</b>	Clock Time	Local Computer Time or ESU TimeStamp (if configured) (hh:mm:ss:ms)
<b>D</b>	class_higheng	Z-Score of High Engagement Probability (-99999 if it falls within Z-score computation window)
<b>E</b>	class_loweng	Z-Score of Low Engagement Probability (-99999 if it falls within Z-score computation window)
<b>F</b>	class_distraction	Z-Score of Class Engagement Probability (-99999 if it falls within Z-score computation window)
<b>G</b>	class_drowsy	Z-Score of Class Drowsy Probability (-99999 if it falls within Z-score computation window)
<b>H</b>	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)
<b>I</b>	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)
<b>J</b>	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)
<b>K</b>	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 (8-13Hz 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 (8-13 Hz bin) at Channel POz
I	poz_7	Z-scored PSD (No Kaiser Window) for Gamma (25-40 Hz bin at Channel POz
J	poz_8	Z-scored PSD (No Kaiser Window) for Beta (13-30 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

<b>D</b>	End DP	End Datapoint of the detected artifact
<b>E</b>	Artifact Type	Artifact type (0 - Spike, 1 - Excursion, 2 - Saturation, 3 - EMG, 5 - Eye blink)
<b>F</b>	Channel	Channel in which the artifact was detected (Eye blinks are reported in all channels, hence channel field is empty)
<b>G</b>	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
<b>A</b>	sessionID	.ebs file Name
<b>B</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
<b>C</b>	Start Counter	Count when missed block started (6-bit counter in the headset (debugging))
<b>D</b>	End Counter	Count when missed block stopped (6-bit counter in the headset (debugging))
<b>E</b>	Epoch Start	Starting second (Epoch) of missed block
<b>F</b>	Offset Start	Starting Sample (datapoint or Offest) of missed block (in 1/256sec)
<b>G</b>	Epoch End	Ending second (Epoch) of missed block
<b>H</b>	OffsetEnd	Ending Sample (datapoint or Offest) of missed block (in 1/256sec)
<b>I</b>	Hour	Time of storing to file (or time of first packet AFTER missed blocks)
<b>J</b>	Minute	
<b>K</b>	Second	
<b>L</b>	Millisecond	