COMP 3004 - Final Project (Team 31)

Deliverables:

- Use cases
- Design documentation – structure and behaviour:
  - UML Class diagram
  - Sequence diagrams for these scenarios covering normal and safety operation
  - State diagrams
  - Textual explanation of your design decisions
- Implementation
- Video
- Traceability matrix

Github Repo: https://github.com/GlencoeDev/COMP-3004-Final-Project

NOTE: For clearer view of the any diagrams, the SVG files would be in the Diagrams folder

Use Cases

General Use Case: Use AED to Resuscitate a Patient with Heart Condition

Primary Actors: AED, User, Patient

Stakeholders and Interests: AED, User, Patient

Preconditions: Batteries inside with enough charge to power on, active user, active patient.

Minimal Guarantee: Device attempts to resuscitate the patient.

Success Guarantee: Device is able to successfully resuscitate the patient who then has sinus rhythm, powers off.

Trigger: User presses ON button while device is off

Major Success Scenario:

1. Device is powered on, initializes self-test (Use Case 1)
2. The user places on electrodes pads on patient when instructed
3. Device performs heart rhythm analysis (Use Case 2)
4. Device makes determination whether to:
   a. Shock (Use Case 3) then perform CPR (Use Case 4)
   b. Not shock and perform CPR (Use Case 4)

c. Abort, instruct users of healthy sinus rhythm and power off.

5. Device returns to Step 3, continues until powered off.

Extensions:

1a. At any stage, the device does not have enough battery.

1a1. The device indicates to the user to ‘Change batteries’ and halts operation.

1b. At any stage, the device is powered off by the user.

4c. Device powered itself off after identifying a healthy patient.

Post conditions: Device is powered off.

Use Case 1: Self-test

Primary Actors: AED, User

Stakeholders and Interests: AED, AED manufacturer, User

Preconditions: Batteries inside with enough charge to power on

Minimal Guarantee: In the event of failure, indicate the failure through a red X

Success Guarantee: Self-test passes, all functions operational.

Trigger: User presses ON button while device is off

Major Success Scenario:

1. Verify battery has enough power for operation
2. Verify that electrodes are connected
3. Verify that ECG is operational and ready
4. Verify defib pads are capable to charge and discharge
5. Verify that CPR monitoring and compression depth detection are functional
6. Visual indications are given to let operator know that it is functioning properly (output to console), green

   CHECK is displayed.

Extensions:

1a. AED does not pass self test at any stage

1a1. AED cannot be used as it is not functioning properly, visual indications are given, red X is displayed.

Post conditions: AED is in an operational state and is ready for normal operation.

Use Case 2: Heart Rhythm Analysis

Primary Actors: AED, AED operator

Stakeholders and Interests: AED, patient, AED operator

Preconditions:

- Adhesive electrode pads are properly placed on patient’s bare chest

- Self-test was complete ensuring that all units are operational

Minimal Guarantee: Unable to determine and advise not to shock, moves on to CPR stage.

Success Guarantee:

- AED is able to accurately analyze the patient's heart rhythm and determine whether the condition is shockable.
- AED is able to determine whether to shock or not to shock and move to the next stage accordingly.
- AED identifies the patient as healthy, advises and shuts down the device.

Trigger: AED reaches the stage where electrodes are attached to the patient and ready to read results.

From any of:

1. From the normal operation after indication to user to place electrodes on patients bare chest.
2. From power on where electrodes are already attached to patients bare chest.
3. After CPR is applied for 2 minutes and returns to the analyzing stage.

Major Success Scenario:

1. AED analyzes the patient's heart rhythm with electrodes, to determine whether a shockable rhythm is detected.
2. AED will determine whether to shock, not shock or shut down based on detected rhythm.

1. Ventricular Fibrillation or Ventricular Tachycardia detected then shock advised: indicate "Shock advised" to user and prepare for shock delivery (Use Case 3)
2. Asystole or unable to detect then shock not advised: indicate "No shock advised" to user and move on to CPR stage (Use Case 4)
3. Sinus rhythm then indicates a healthy patient and shuts down the device.

Extensions:

1a1. Device is powered off by the user.

Post conditions: The device makes the decision whether to shock or not to shock and continues on to the respective stage.

Use Case 3: Shock Delivery

Primary Actors: AED, AED operator

Stakeholders and Interests: AED, patient, AED operator, AED manufacturer, batteries

Preconditions: AED has determined that a shock should be delivered to the patient

Minimal Guarantee: Unable to charge electrodes to deliver shock due to insufficient battery, indicates to user to "Change batteries," then prompts the user to confirm the battery replacement.

Success Guarantee: AED charges electrodes and successfully delivers shock to patient.

Trigger: AED indicated shock advised

Major Success Scenario:

1. Indicate “Shock advised.”
2. Indicate “Stand clear, do not touch the patient.”
3. Begin charging battery to deliver shock.
4. Timer will count down from 3 and deliver shock to the patient.
5. Indicate “Shock delivered.” Increase shocks delivered counter.
6. If more than one shock delivered since power on, indicate “n shocks delivered.”

Extensions:

3a. Not enough battery charge to deliver shock
3a1. Indicate to the user “Change batteries.”
3a2. Prompt the user to confirm battery replacement.
3a3. If user confirms, replace batteries and return to the Major Success Scenario at step 3.
3a4. If user cancels or if insufficient battery charge persists, indicate "Unable to deliver shock due to low battery" and exit the use case.

Post conditions: CPR can be administered (Use Case 4)

Use Case 4: Perform CPR

Primary Actors: AED, AED operator

Stakeholders and Interests: AED, AED operator, patient

Preconditions: Either:

1. Shock has been delivered to patient
2. Shock was not advised

Minimal Guarantee: Advise the user to perform CPR, time the 2 minutes, stop CPR and return to analyzing stage.

Success Guarantee: Advise the user to perform CPR, time the 2 minutes, indicate whether user should push harder as needed, stop CPR and return to analyzing stage.

Trigger: AED moved into CPR stage after either shock advised and delivered (Use Case 3) or no shock advised from analyzing stage (Use Case 2).

Major Success Scenario:

1. Indicate “Start CPR”.
2. Start a local timer for 2 minutes.
3. Continuously monitor the users compression depth
    a. If the user is not pushing within 2-2.4in, indicate “Push harder”.
    b. When the user succeeds 2-2.4in, indicate “Good compressions” prompt, continue monitoring.
4. After the 2 minute timer expires, indicate “Stop CPR”.
5. Move to analyzing stage to determine another shock (Use Case 3)

Extensions:

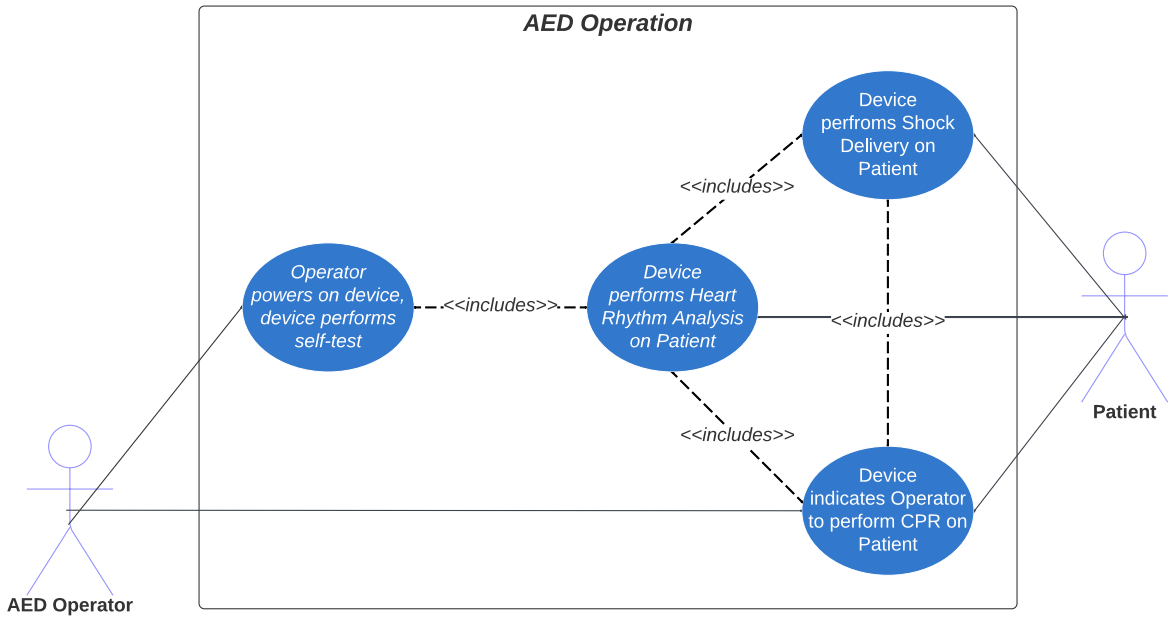
1a. At any stage, the user powers off the device.

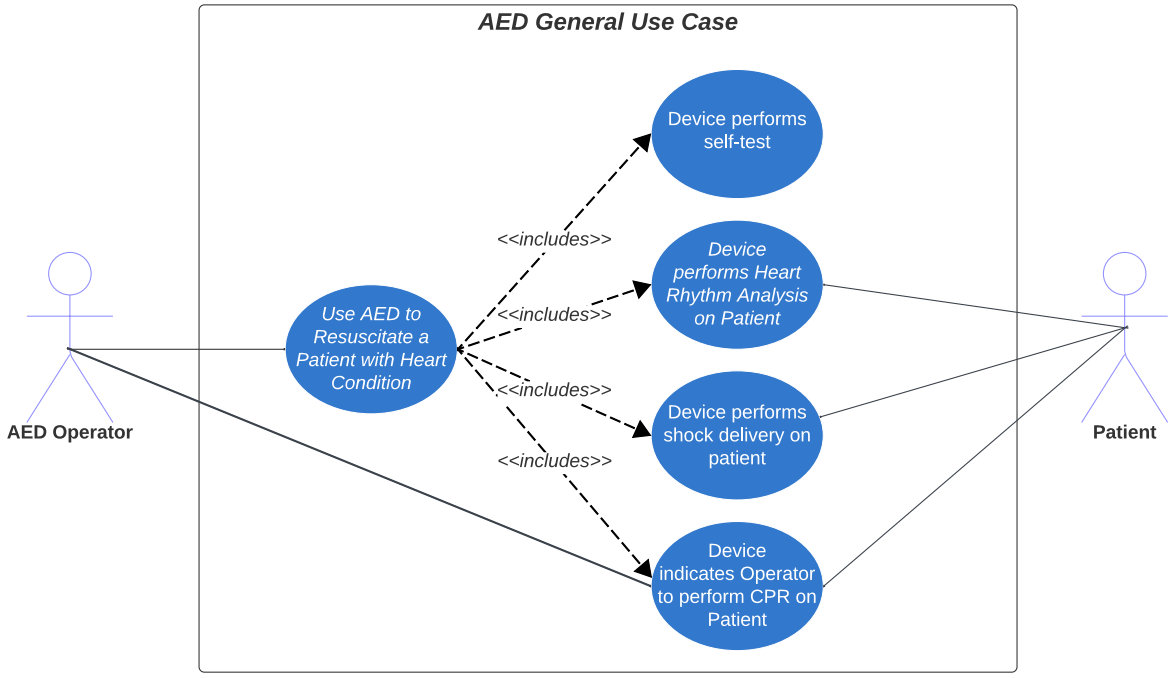
3a. Defib pads disconnected, cannot identify compression depth

3a1. Continue as normal without providing feedback

Post conditions: Analyzing heart condition (Use Case 3)

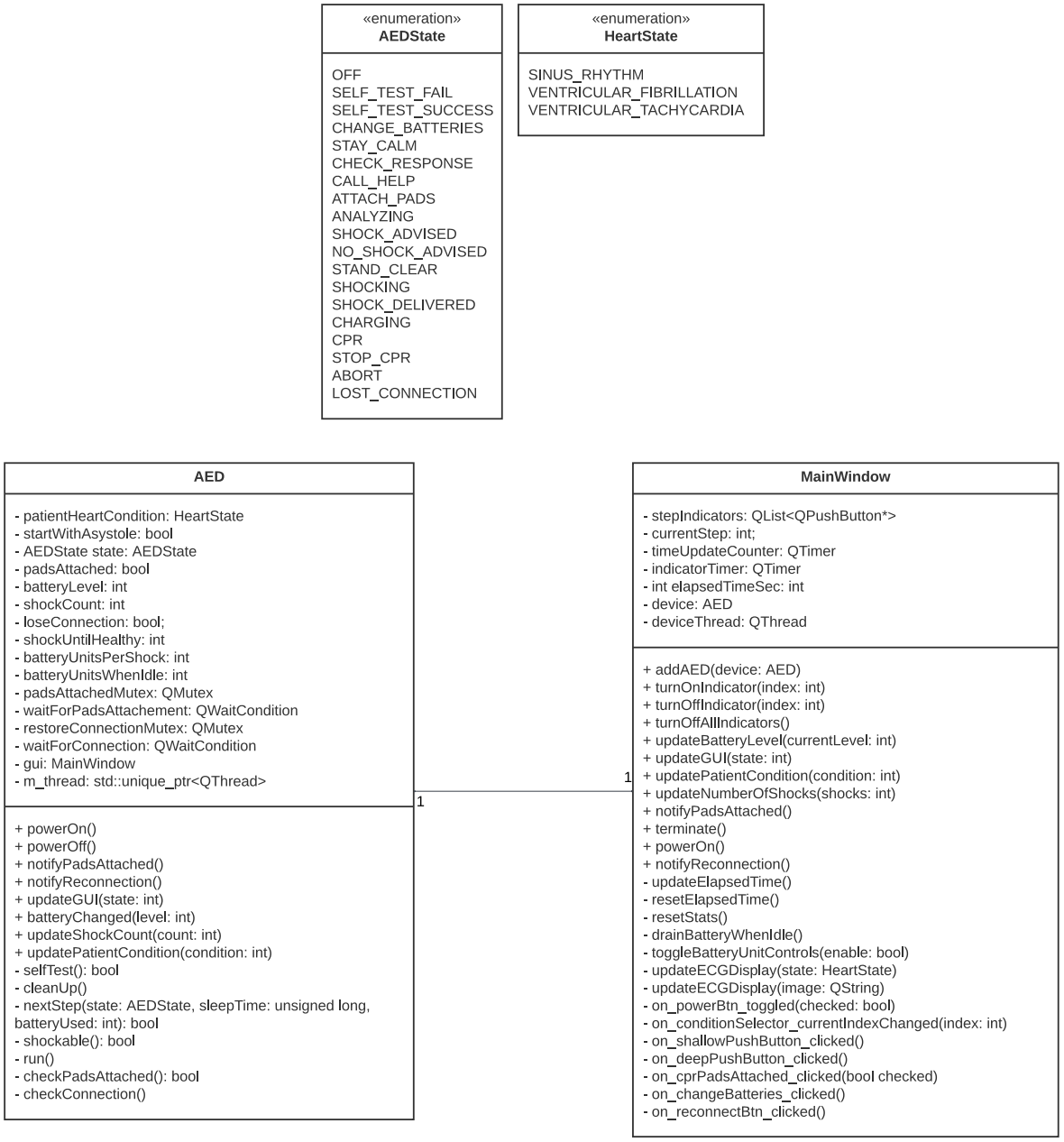
Use Case Diagram





Design documentation

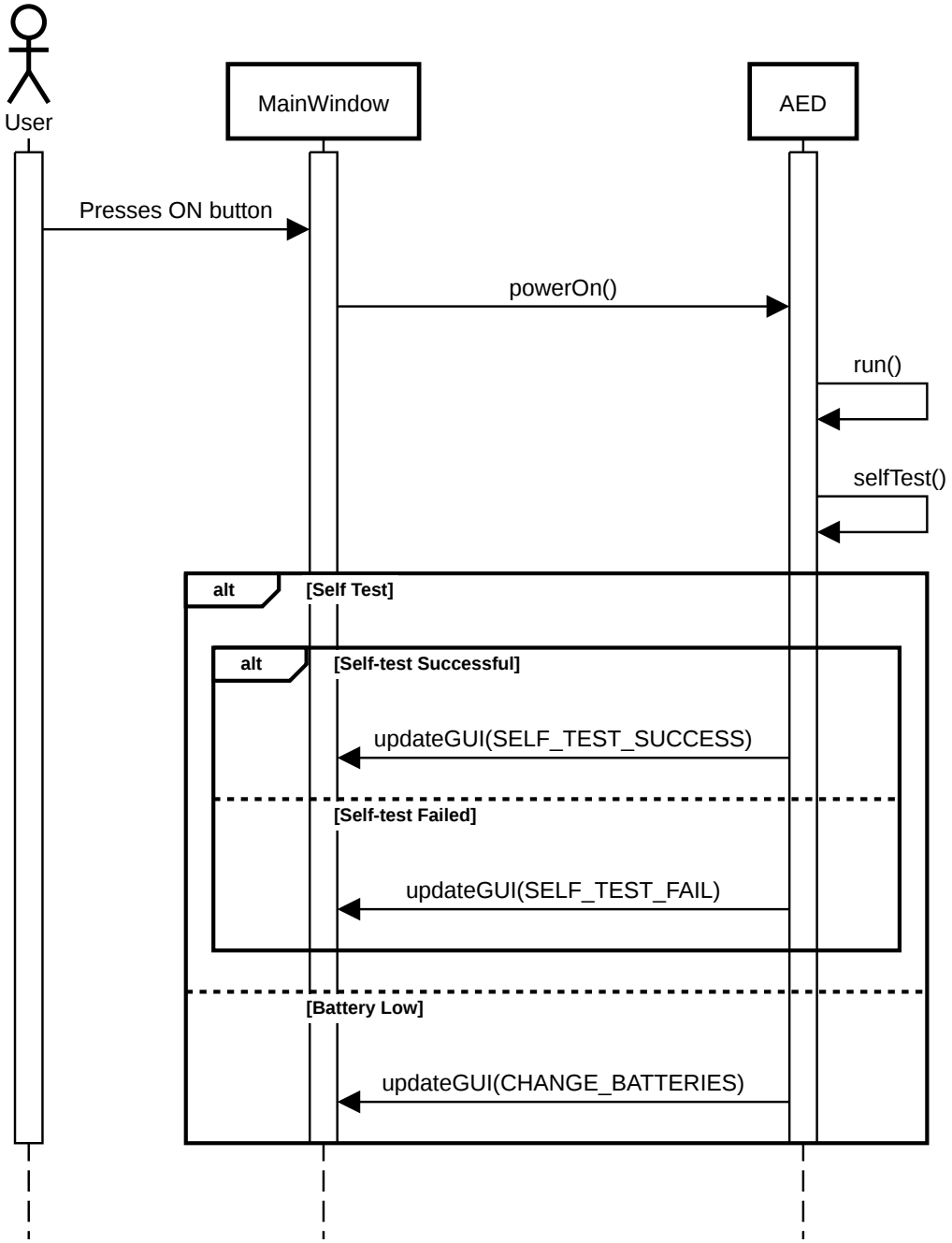
UML Diagram



Sequence diagrams

Success Scenarios

Success Scenario For Self-test



Breakdown of sequence diagram:

- The diagram starts with three participants: User, MainWindow (assumed to be the graphical interface), and AED (Automated External Defibrillator).
- Activation of User, MainWindow, and AED indicates their involvement in the scenario.
- The User initiates the process by pressing the ON button on the MainWindow.
- The MainWindow then sends a `powerOn()` message to the AED.
- An alternative (alt) sequence is introduced for the self-test. If the self-test is selected:

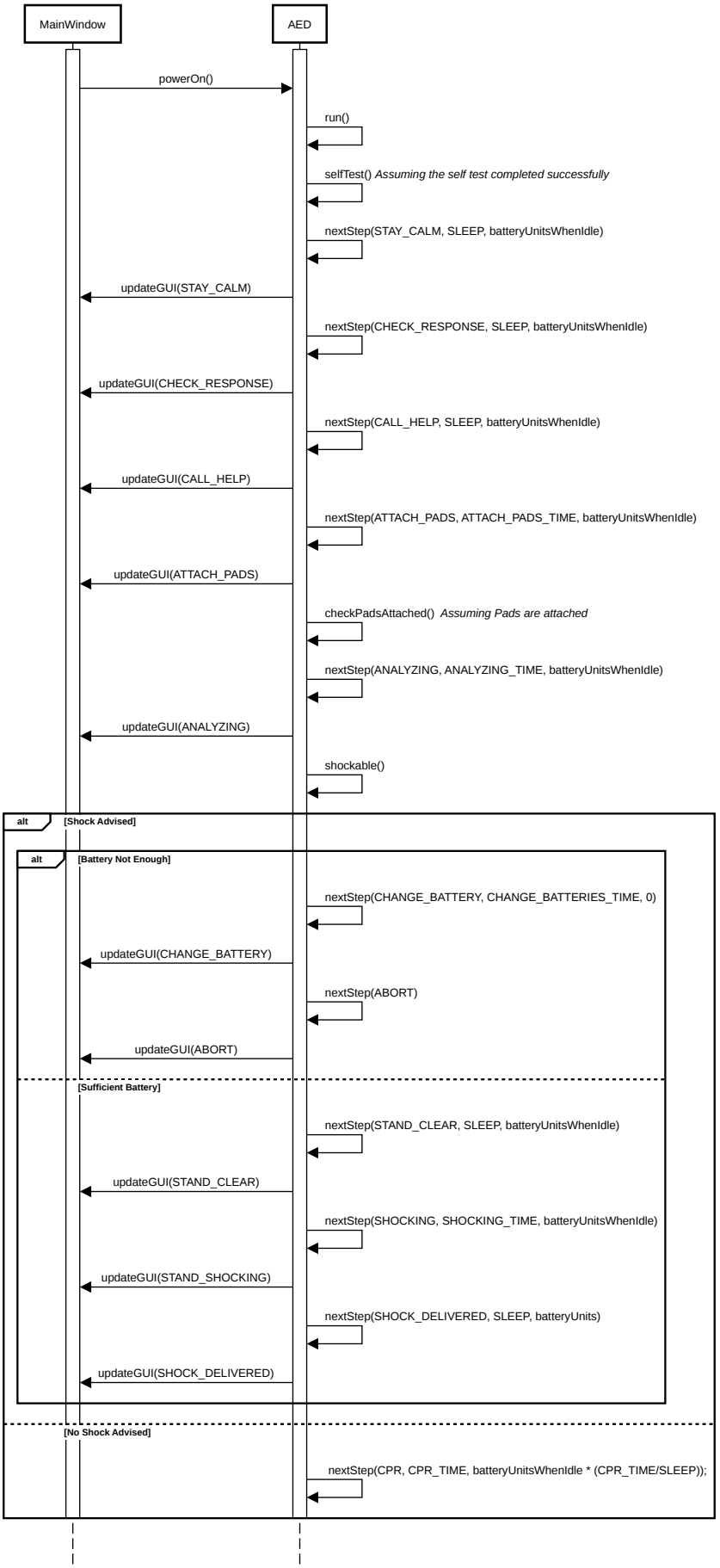
    - The AED performs a self-test by running `run()` which call the `selfTest()` function.
    - Within the self-test, there is another alt sequence:
        - If the self-test is successful, the AED sends a success message to the MainWindow using `updateGUI(SELF_TEST_SUCCESS)`.
        - If the self-test fails, the AED sends a failure message to the MainWindow using `updateGUI(SELF_TEST_FAIL)`.
- If the self-test alt sequence is not taken (else clause), it checks for a low battery. If the battery is low, the AED sends a message to the MainWindow indicating the need to change batteries using `updateGUI(CHANGE_BATTERIES)`.
- Finally, all participants (User, MainWindow, and AED) are deactivated, indicating the end of the sequence.

This sequence diagram provides a visual representation of the interactions between the User, MainWindow, and AED during a successful self-test scenario.

Safety Scenarios

Scenario 1: Shock Delivery

Shock Delivery Sequence Diagram

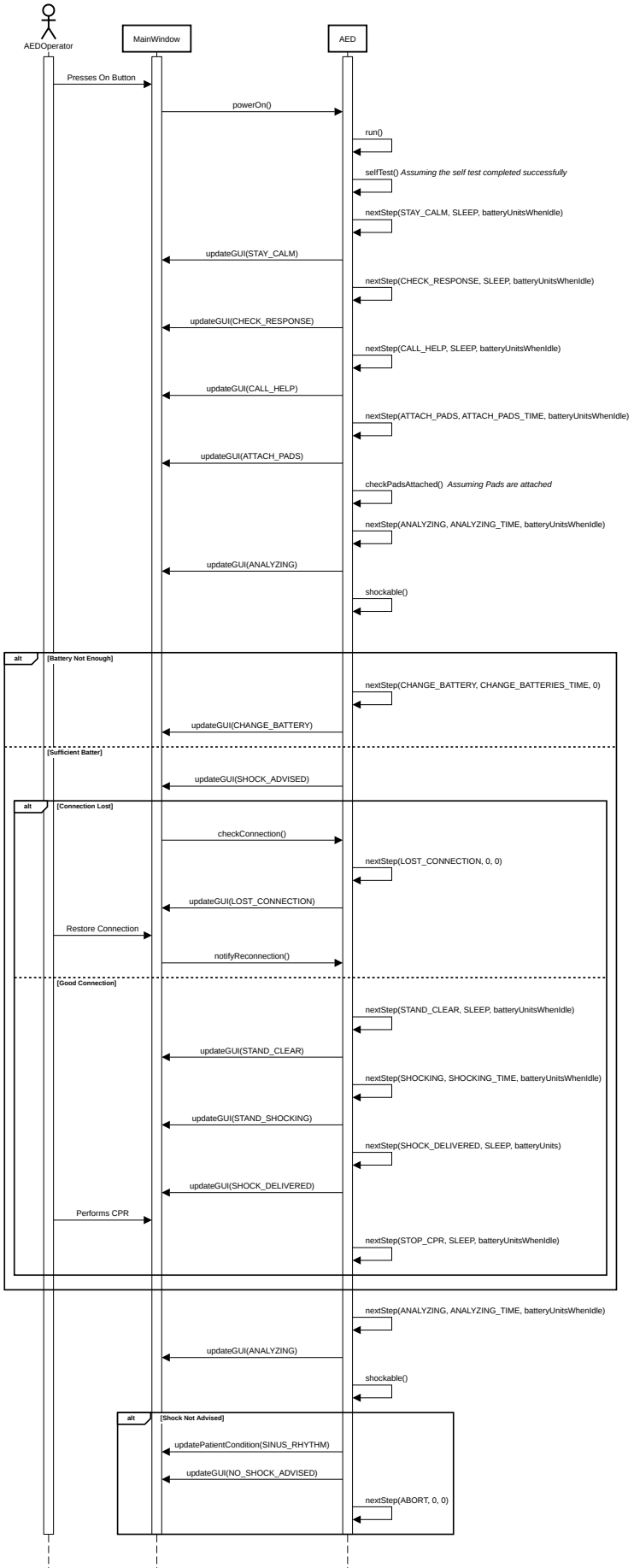


Breakdown of sequence diagram:

- This sequence diagram illustrates the sequence of events in the Shock Delivery process using an AED.
- The MainWindow activates the AED, which then undergoes a series of steps, including self-testing, providing instructions to the user, checking for pad attachment, analyzing the patient's condition, and determining if a shock is advised.
- Depending on whether a shock is advised or not, different paths are taken:
    - If a shock is advised, the AED checks the battery status. If the battery is not sufficient, it initiates a battery change and updates the GUI. If the battery is sufficient, it proceeds with the shock delivery process, updating the GUI at each step.
    - If no shock is advised, the AED initiates CPR and updates the GUI accordingly.
- Finally, all participants (AED and MainWindow) are deactivated, indicating the end of the sequence.

Scenario 2: Resuscitating Patient with Ventricular Fibrillation

Resuscitating Patient with Ventricular Fibrillation

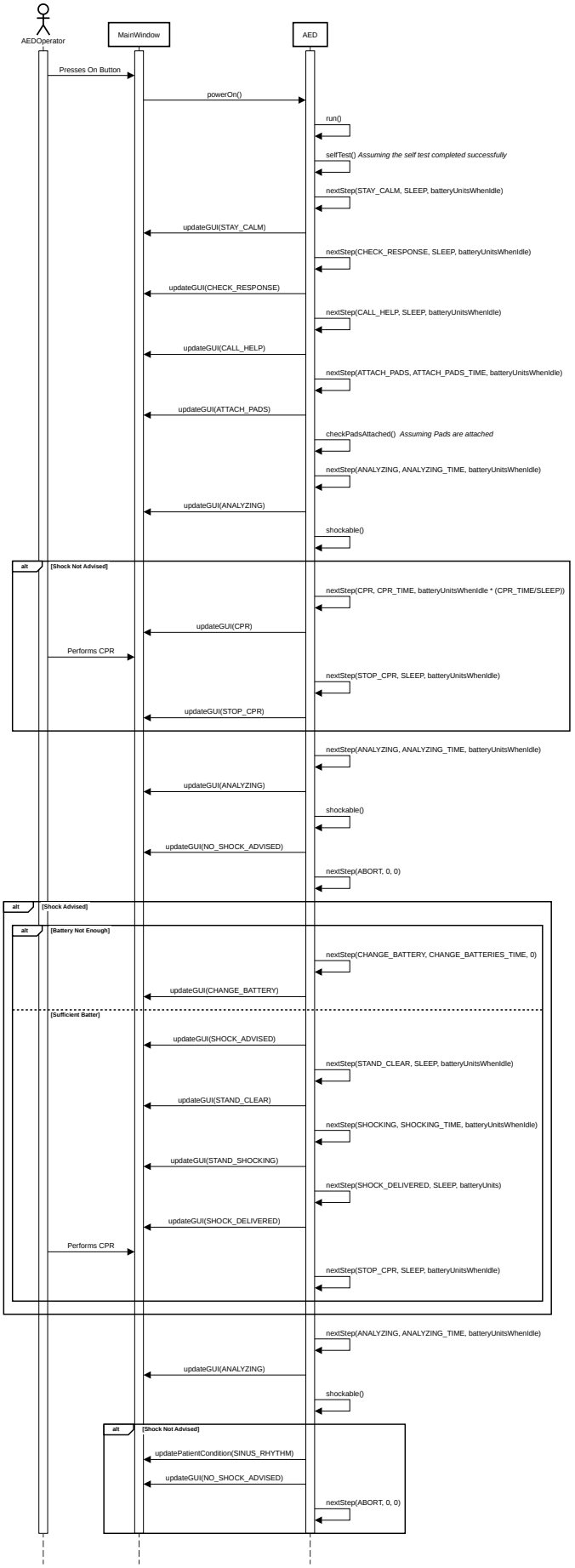


Breakdown of sequence diagram:

- The sequence diagram depicts the steps involved in the process of resuscitating a patient with ventricular fibrillation using an AED.
- The AEDOperator initiates the process by pressing the On Button on the MainWindow.
- The AED goes through several steps, including a self-test, providing instructions to the user, checking connection status, delivering a shock if advised, and performing CPR.
- The diagram includes alternative paths (alt) based on conditions such as battery status, connection status, and whether a shock is advised or not.
- Messages are exchanged between the AED, MainWindow, and AEDOperator to update the graphical interface, notify conditions, and perform necessary actions.
- Finally, all participants (AED, MainWindow, and AEDOperator) are deactivated, indicating the end of the sequence.

Scenario 3: Resuscitating Patient with Ventricular Tachycardia and Asystole

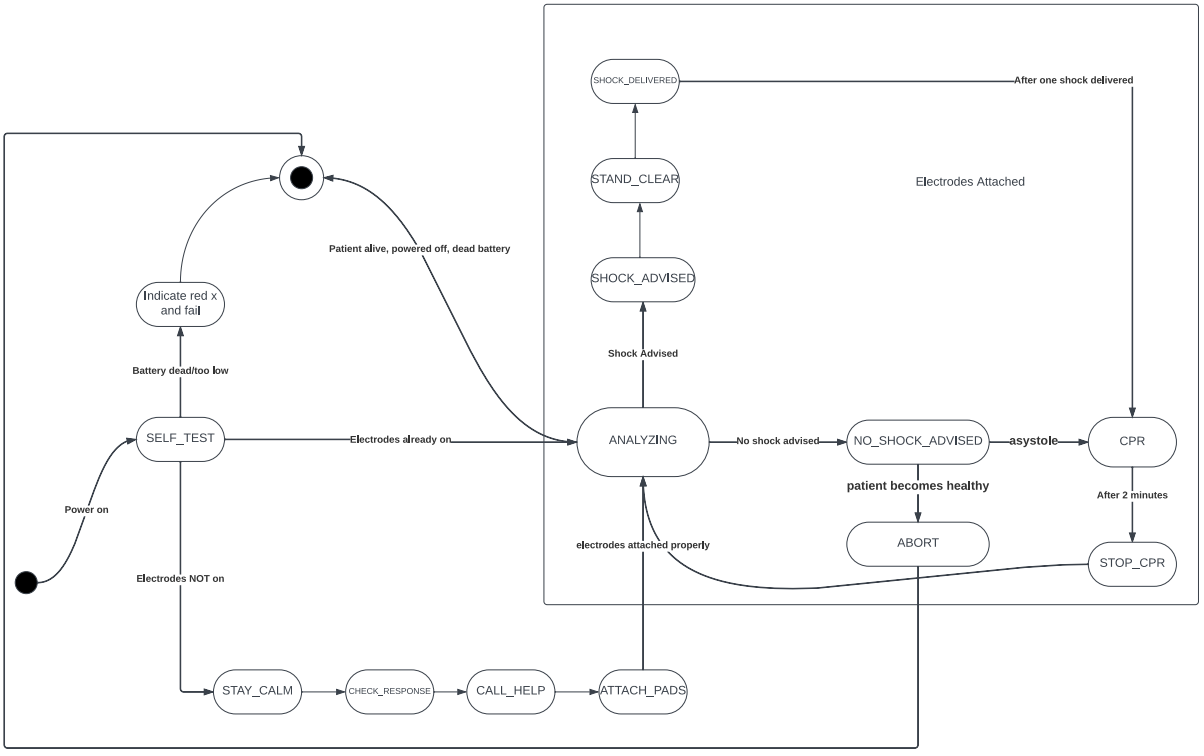
Resuscitating Patient with Ventricular Tachycardia and Asystole



Breakdown of sequence diagram:

- This sequence diagram depicts the steps involved in the process of resuscitating a patient with ventricular tachycardia and asystole using an AED.
- The AEDOperator initiates the process by pressing the On Button on the MainWindow.
- The AED goes through several steps, including a self-test, providing instructions to the user, checking connection status, delivering a shock if advised, and performing CPR.
- The diagram includes alternative paths (alt) based on conditions such as shock advisement, battery status, and whether CPR is required.
- Messages are exchanged between the AED, MainWindow, and AEDOperator to update the graphical interface, notify conditions, and perform necessary actions.
- Finally, all participants (AED, MainWindow, and AEDOperator) are deactivated, indicating the end of the sequence.

AED State Diagram



Textual Explanation

Introduction & Design Patterns

The organization of the system is a MainWindow class which handles primarily just the button presses, updating indicator lights, and updating the LCD display and an AED class which handles the actual logic and operation of the AED. The AED class has its own thread in order to avoid blocking the GUI updates. We implemented the waiting time between each class using Qthread::sleep, because

otherwise putting them in the same thread will block the UI from updating. We used an observer design pattern on AED so when the AED changes the state it will notify the MainWindow class to update the UI accordingly. The framework itself is working on the observer design pattern through signal and slot mechanism. Further, inside the framework, we have a singleton design pattern where QCoreApplication only has one instance.

The communication between threads is handled using QMutexLock to avoid race conditions. At first, when checking the pad some race conditions wouldn't update the state properly and the system would keep waiting for the pads to be attached.

We tried to decouple things as much as possible, such as putting the definitions in one place, so that when we need to change anything, we only need to change it in one place.

Time Variation

There are several variations from the original *ZOLL AED Plus* provided in order to make testing and usage easier and less unnecessarily time-consuming. One of the most notable variations is the time that the device is in each state, these times are defined in the defs.h file, which will make it easier to modify later, and include things like only making the CPR time 10 seconds rather than 2 minutes, alongside minimizing the analyzing time for the heart rhythm, charging and shocking time.

Battery Life Variation

The other notable variation is the battery life depletion. Default operation depletes the battery life by 1% every second, and 1% for shocks. However, at the start of the program, these are very easy to change within the GUI in the admin/testing panel. This differs as the real-world device is rated for +-225 shocks on a single charge, however, we are required to visually show a change in battery life on usage. Device battery life is also preserved throughout the runtime of the program and can be changed in the same admin/testing panel when the device is powered off.

Asystole case

We have one case to handle when the asystole rhythm occurs. In this case, we assume that after one shock the patient will go back to another shockable rhythm to continue performing CPR. We will also increase the number of shocks to be delivered for the asystole rhythm by one.

Deep, shallow CPR

There are only two cases in which AED will provide feedback to the operator when doing CPR, which is good stroke and shallow stroke. Thus we implemented two buttons to handle these cases just for the ease of testing. But in our implementation, we can easily change it to show different CPR depths and provide feedback.

Video Presentation: https://youtu.be/YdA5Hi0-f5M

Traceability Matrix

ID	Requirement	Related Use Case	Fulfilled By	Tested By	Description
1	The application initiates a device self-test to ensure	Self-test (UC1)	AED	Clicking the power button on the GUI, waiting for either “UNIT	The AED initiates a self-test to ensure that the device

	functionality when powered on.			OK” or “UNIT FAILED” on the LCD display.	is functioning properly and ready for use.
2	The application provides a visual and audible indication that the device is ready to use.	Self-test (UC1)	AED, MainWindow	Click the power button on the device. Wait until it displays “UNIT OK” on the LCD display and audibly (displayed in the audio display textbox). The self-test indicator turns green.	Once the AED is fully operational, it will provide a visual and audible indication.
3	The application analyzes the heart's electrical activity to determine if a shockable rhythm, such as ventricular fibrillation or ventricular tachycardia, is present.	Heart Rhythm Analysis (UC2)	AED	Power on the device and wait until the AED is in the heart rhythm analysis stage. Device will display “ANALYZING”, and make a decision based on the result of the analysis.	AED analyzes the heart’s electrical activity to determine the current rhythm. Possible determinations are ventricular fibrillation, ventricular tachycardia, asystole and sinus rhythm.
4	The device provides cardiovascular arrhythmia diagnosis results.	Heart Rhythm Analysis (UC2)	AED, MainWindow	Power on the device and wait until the AED is in the heart rhythm analysis stage. The device will display the result of the analysis on the LCD display.	AED provides the result of the diagnosis to MainWindow for the user to see.
5	The device display shows the information simulated ECG waveform.	Heart Rhythm Analysis (UC2)	AED, MainWindow	Power on the device and wait until the AED is in the heart rhythm analysis stage. Once the analysis is complete, the device will show a graph of the heart condition	AED provides the result of the diagnosis as a graph to MainWindow for the user to see.

				on the LCD display.	
6	The application provides a message on the screen and provides textual explanations on the next steps to deliver a shock when a shockable rhythm is detected.	Heart Rhythm Analysis (UC2)	AED, MainWindow	Select one of the shockable conditions in the control panel, power on the device and wait until the AED is in the heart rhythm analysis stage.The device will show the message on the LCD display and update as it moves through the stages of delivering a shock, when a shockable rhythm is detected.	If a shockable rhythm is detected, the device will indicate ‘Shock advised’ to the user, and will begin to prepare for the shock. Advising the user to stand clear of the patient as it charges itself.
7	AED delivers shock to patient	Shock Delivery (UC3)	AED	Select one of the shockable conditions in the control panel, power on the device and wait until the AED is in the shocking stage. When the AED determines a shock is necessary, it will deliver the shock after a 3 second countdown and adjust battery accordingly.	When the device is charged and ready to deliver shock, it will display a countdown from 3 and will deliver shock to the patient.
8	The AED instructs the user to perform CPR for a specified duration after delivery of a shock or	Perform CPR (UC4)	AED, MainWindow	Select one of the shockable conditions in the control panel, power on the device and wait until the AED is in the CPR stage. The device will	After shock is delivered, the device will start a 2 minute timer and advise the user to ‘Start CPR’. After 2 minutes, it will advise ‘Stop CPR’.

				display via the LCD display and the audio textbox to “Start CPR”, and when to “Stop CPR”.	
9	The application provides a textual explanation on how to deliver a CPR when a non-shockable rhythm is detected.	Perform CPR (UC4)	AED, MainWindow	Select one of the shockable conditions in the control panel and check the ‘Start with Asystole’ checkbox. Power on the device and wait until the AED is in the CPR stage. The device will show on the LCD the depth of the compressions and provide feedback on “Push harder” or “Good compressions”.	After shock was not advised, the device will start a 2 minute timer and advise the user to ‘Start CPR’. After 2 minutes, it will advise ‘Stop CPR’.
10	The device display provides visual and textual feedback to the user on the quality of CPR compressions.	Perform CPR (UC4)	AED, MainWindow	Select one of the shockable conditions in the control panel, power on the device and wait until the AED is in the CPR stage. Press “Deep Stroke” and “Shallow Stroke” to imitate CPR delivery. The device will show on the LCD the depth of the compressions and provide feedback on “Push harder” or “Good compressions”.	During the 2 minute CPR period, the device will analyze the depth of the CPR compressions and provide either ‘Push harder’ if the depth is not within 2-2.4in, or ‘Good compressions’ if they are. Will continue to monitor during the 2 minute period.

11	The application provides clear voice and visual prompts to guide the user during operation.	All use cases (UC1, UC2, UC3, UC4)	AED, MainWindow	Power on the device. Observe the prompts provided by the application via both the LCD display and audibly (which is simulated through an audio display textbox.)	Throughout the operation of the device, the device will provide textual feedback through the LCD display to indicate to the user important information and the current/next stages. Device will also output messages in the audio box simulate in the control panel to simulate *audio messages*.
12	The device has an indicator for battery status.	N/A	AED, MainWindow	Power on the device, and observe the battery indicator showing battery level in the top right of the device window (left to the control panel).	Device will have an indicator showing the current battery status. This indicator will be updated throughout use and after shock(s) is/are delivered.
13	The device has a button for electrode placement.	N/A	AED, MainWindow	Click on the “Attach Pads” image in the control panel. When clicked, the electrodes are attached to the patient.	Device has a button on the GUI that will allow the user to simulate the placing of the electrodes on the patient to begin heart rhythm analysis and move on to the next stages.
14	The device display shows the device status.	N/A	AED, MainWindow	Power on the device and observe the LCD display that will show the device status throughout operation.	The device display will indicate the time elapsed since the device was powered on, current shock count, as well as

					the textual message indicating current step of the device operation.