

Project Title: System Verification and Validation Plan for Chess Connect

Team #4,
Alexander Van Kralingen
Arshdeep Aujla
Jonathan Cels
Joshua Chapman
Rupinder Nagra

April 5, 2023

1 Revision History

Table 1: Revision History

Date	Developer(s)	Change
2022-10-31	Jonathan Cels	NFR Testing
2022-10-31	Arshdeep Aujla	Added section 3
2022-11-02	Jonathan Cels	Traceability matrix
2022-11-02	Joshua Chapman	Section 4.1,4.2,4.3,4.4
2022-11-02	Rupinder Nagra	Section 5.1
2022-11-02	Joshua Chapman	Section 4.1, 4.2, 4.3, 4.5
2022-11-02	Alexander Van Kralingen	Completed Section 4.4, 4.6, 4.7
2023-04-04	Alexander Van Kralingen	Updated abbreviation table and added reference links to other documents.
2023-04-04	Alexander Van Kralingen	Modified Software Design Verification to be less code specific and more focused on the overall architecture of the source code.
2023-04-04	Alexander Van Kralingen	Modified Software Implementation Verification to address more codebase specific verification elements.
2023-04-04	Alexander Van Kralingen	Clarified GA-4, GA-5, GI-5, EA-3, NFT-11
2023-04-04	Alexander Van Kralingen	Added "-" to NFT requirement numbers
2023-04-04	Alexander Van Kralingen	Added NFT-13, 14 and 15.
2023-04-04	Alexander Van Kralingen	Updated Traceability table to reflect requirement changes.

Contents

1	Revision History	i
2	Symbols, Abbreviations and Acronyms	iii
3	General Information	1
3.1	Summary	1
3.2	Objectives	1
3.3	Relevant Documentation	1
4	Plan	2
4.1	Verification and Validation Team	2
4.2	SRS Verification Plan	2
4.3	Design Verification Plan	3
4.4	Verification and Validation Plan Verification Plan	3
4.5	Implementation Verification Plan	3
4.6	Automated Testing and Verification Tools	4
4.7	Software Validation Plan	5
5	System Test Description	6
5.1	Tests for Functional Requirements	6
5.1.1	Game Active State	6
5.1.2	Game Inactive State	8
5.1.3	Normal Mode	10
5.1.4	Engine Mode	12
5.1.5	Beginner Mode	16
5.2	Tests for Nonfunctional Requirements	20
5.2.1	Look and Feel	20
5.2.2	Usability and Humanity	20
5.2.3	Performance	22
5.2.4	Security	25
5.3	Traceability Between Test Cases and Requirements	27

2 Symbols, Abbreviations and Acronyms

Table 2: Abbreviations used in this document

symbol	description
LED	Light Emitting Diode
I/O	Input/Output
IDE	Intergrated Development Environments
UI	User Interface
API	Application Program Interface

3 General Information

3.1 Summary

The project name is Chess Connect. It is comprised of software and hardware components. The hardware will consist of a reactive chess set connected to a microcontroller. The microcontroller will relay information on the chess board in the form of LEDs of the possible moves the user can make. The software component of this project will consist of a web application that will reflect all of the chess piece's location on the physical board.

3.2 Objectives

The following objectives are the qualities that are the most important for the project.

- The hardware should reflect relevant information on the LEDs on the chess board
- The software component should reflect the physical chess board in near-real time
- The movement of the chess pieces should be recorded by the hardware

3.3 Relevant Documentation

The following documents are relevant to this project.

- [Development Plan](#)
- [SRS](#)
- [Hazard Analysis](#)
- [MIS](#)
- [MG](#)
- [VnV Report](#)

4 Plan

This section discusses the general plans for hardware and software testing. The responsibilities of members are assigned and requirements verifications are discussed. Design and implementation verification include high-level plans to execute hardware and software systems. Automated testing techniques and tools are outlined. A detailed software validation plan discusses the external tools required for completeness.

4.1 Verification and Validation Team

Table 3: Validation team members and responsibilities

Alexander Van Kralingen	Web application connection tests GitHub integration testing Microcontroller code testing
Arshdeep Aujla	Sensor accuracy testing Microcontroller hardware & code testing Touchscreen UI latency tests
Jonathan Cels	Microcontroller code testing Chess API integration testing Communication protocol testing
Joshua Chapman	Power distribution design and integration testing Microcontroller hardware & code testing Communication protocol testing
Rupinder Nagra	Chess API integration testing Web application connection tests Web application functionality testing

4.2 SRS Verification Plan

SRS verification is performed by the teammates throughout the design and testing process. They will reference requirements and consider the results throughout design. Teammates will periodically verify this completeness

throughout the design process. The verification and validation report will reference an associated requirement for each test. This allows for tracking of individual requirement fulfillment throughout the process.

4.3 Design Verification Plan

Hardware Design Verification begins with LTSpice and Multisim design software packages. The designed circuits are simulated in the software and tested accordingly. Testing includes simulating inputs and verifying that expected outputs are returned. Edge cases are simulated to verify safety and failure conditions of the circuits.

Software Design Verification The software will be built to handle all of rules for the game of chess. Chess logic and rules will be compared to existing standards for verification. The [MG](#) will be used as a guide to ensure that our code covers all of the requirements listed in the [SRS](#). Feedback from evaluators will be considered alongside feedback from peers, and testing will help to ensure robustness and a thorough coverage of all possible user actions. The software is intended to cover all scenarios within reason, and failed tests will help to pinpoint where the design of the software has room for improvement.

4.4 Verification and Validation Plan Verification Plan

The Verification and Validation Plan verification will include reviewing the [Verification and Validation Plan checklist](#) and adjusting this document accordingly. The verification will also include considering feedback from issues created by another team, as well as from the TA assigned to this project. Comments and improvements will be implemented after completing revision 0 of this document.

4.5 Implementation Verification Plan

Hardware Implementation Verification begins with individual components. First the power supply is tested with a voltmeter for accuracy and precision. Then, the microcontroller is powered on and each individual I/O is tested for correctness. Inputs will be powered via the power supply and readings are verified for correctness using custom testing software installed on

the controller. Outputs are verified using the voltmeter to measure correctness relative to the controller value. Finally, sensors and circuits are tested using the IO of the microcontroller. This allows for accurate and detailed inspection of the components and verifies their correctness.

Software Implementation Verification requires the hardware to be tested and assembled before beginning. Arduino IDE contain the tools to compile and check for syntax errors. Code walkthroughs are performed by collaborators that did not write the program. This includes detailed inspection and a report describing the function of the code based on their perspective. This tests the readability and functionality of the code. The software is downloaded to the controller and the I/Os are configured one-by-one. Functionality of code is tested with unit tests from section 5.1 with the appropriate hardware. Once each section is unit tested, the sub-systems can begin to combine to test completeness of full systems and their functionality.

4.6 Automated Testing and Verification Tools

Automated testing will be carried out for the software involved with this project. Unit tests will be created to test the functionality fo each function created for the program. A minimum of one “successful” test will be written to describe the intended program execution, and one or more “unsuccessful” tests will be written to test the robustness of the program. This will ensure complete code coverage for the software. There are 3 main classes of tests that will be run involving the different aspects Chess Connect:

- **Linting:** Performed on Python and Javascript code. This will be integrated into VS Code to assist in local development; this will be run as a Github Workflow as a non-blocking check before building the software.
 - [ESLint](#) to be used for Javascript
 - [Flake8](#) to be used for Python
- **Unit Tests:** Detailed in Section ??, unit tests will be performed for Python, Javascript and C code.
 - [React Testing Library](#) will be used for Javascript unit tests.

- [PyTest](#) will be used for Python unit tests.
- [AceUnit](#) will be used for C unit tests.
- **Dynamic Analysis Tool:** in addition to creating unit tests for the C code, memory leaks and access errors will be caught using [ValGrind](#).

Debuggers: Dynamic analysis will also be performed on the code through debuggers to verify the system and unit tests, as well as normal operation. These tools will be used extensively to bring all unit tests to a successful state, and to determine the root cause of any inconsistent behaviour from the hardware.

- The browser's (Chrome, Firefox, etc.) built in debugger will be used for stepping through the Javascript code on the web application.
- [pdb](#) will be used for Python debugging.
- [Arduino Zero Built-in Debugger Interface](#) will be used for debugging embedded C code.

4.7 Software Validation Plan

Software will be validated by reviewing the requirements in the [Software Requirement Specifications](#) document and ensuring the software matches the expected performance and behaviour. The chess engine software integration will be validated by comparing it alongside an established online chess engine running the same Stockfish build as is selected for Chess Connect, and comparing the recommended moves. One website that may be used is [365Chess.com](#).

Feedback from members of the team that are assigned to another area of the system will be called to verify the software is performing adequately. For example, a member working on the web application may come to test the hardware to ensure the sequences and behaviour is intuitive and user friendly. Feedback and comments from the professor and TA assigned to this project will also be considered when making adjustments to the software.

Unit tests will be created that capture both normal-use and failure modes to validate the software as well. Unit tests will be integrated in a Github

workflow to ensure that changes are never made to the software that conflict with other areas of the code. Failing unit tests will be used as direction to change parts of the software back to a valid state of operation.

5 System Test Description

5.1 Tests for Functional Requirements

The following functional requirements are split into subsections that describe the Active and Inactive states of the system, and the behaviour for the different user modes of the application. Each of the user modes include distinct actions due to the purposes of each mode.

5.1.1 Game Active State

1. GA-1

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Active State.

Input: The user will press the Resign/Draw button.

Output: The system will be changed to the Game Inactive State.

Test Case Derivation: The game shall be in the Game Inactive State due to the Resign/Draw button being pressed.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state has been modified.

2. GA-2

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Active State.

Input: The user will press the New Game button.

Output: The system will be unchanged.

Test Case Derivation: The game shall remain in the Game Active State after the New Game button is pressed.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see that the game state has not been modified.

3. GA-3

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Active State.

Input: The user will switch to one of the user modes (Normal Mode, Engine Mode, Beginner Mode).

Output: The system will be changed to the selected user mode.

Test Case Derivation: The game shall be in the selected user mode due to the appropriate user mode switch being pressed.

How test will be performed: The function that changes the user mode will be run using the appropriate inputs. After it has ran we will check to see if the user mode has been modified.

4. GA-4

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Active State.

Input: The game is terminated.

Output: The display the final game and message with the game termination type (stalemate, checkmate, resignation, draw).

Test Case Derivation: The game shall output the final game and message due to the game being terminated.

How test will be performed: The function that handles actions after game termination will be run using the appropriate inputs. After it has ran we will check to see if the final game and message with termination type are displayed.

5. GA-5

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Active State.

Input: stalemate() calculates a stalemate; or checkmateWhite() or checkmateBlack() calculates a checkmate.

Output: The game state will be changed to the Game Inactive State.

Test Case Derivation: The game shall be changed to the Game Inactive state due a stalemate or checkmate ending the game.

How test will be performed: The function that modifies the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state has been changed to the Game Inactive State based on the the checkmate or stalemate termination type.

5.1.2 Game Inactive State

1. GI-1

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Inactive State.

Input: The user will press the New Game button.

Output: The system will be changed to the Game Active State.

Test Case Derivation: The game shall be in the Game Active State due to the New Game button being pressed, starting the game at the default position.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state has been modified to the Game Active State.

2. GI-2

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Inactive State.

Input: The user will try to switch to one of the user modes (Normal Mode, Engine Mode, Beginner Mode).

Output: The system will be unchanged to the selected user mode.

Test Case Derivation: The game state shall be unchanged due to the user mode appropriate switch being pressed in the Game Inactive State.

How test will be performed: The function that changes the user mode will be run using the appropriate inputs. After it has ran we will check to see if the game state has been unmodified.

3. GI-3

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Inactive State.

Input: The user will press the Resign/Draw button.

Output: The system will be unchanged.

Test Case Derivation: The game shall be in the Game Inactive State due to the Resign/Draw button having no effect.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state is unchanged.

4. GI-4

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Inactive State.

Input: The user will move a piece.

Output: The board state is not sent to the web application.

Test Case Derivation: The board state will not be sent due to the Resign/Draw button having no effect as it is in the Game Inactive State.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state is unchanged.

5. GI-5

Type: Functional, Dynamic, Manual

Initial State: The game is in the Game Inactive State.

Input: The game is changed to the Game Active State.

Output: The game state will be reset to the starting position.

Test Case Derivation: The game shall be reset to the default starting position due to it entering the Game Active State.

How test will be performed: The function that resets the starting position will be run using the appropriate inputs. After it has ran we will check to see if the board state has been reset to the starting position.

5.1.3 Normal Mode

1. NB-1

Type: Functional, Dynamic, Manual

Initial State: The game is in Normal Mode.

Input: A piece has been moved to a square.

Output: The system stores the position, colour, and type of piece in the micro-controller.

Test Case Derivation: The system should contain the position, colour, and type in the micro-controller after a piece has been moved to a square in order to track the board state for the web application.

How test will be performed: The function that accesses the micro-controller will be run using the appropriate inputs. After it has ran we will check to see if the position, colour, and type of piece are stored in the micro-controller.

2. NB-2

Type: Functional, Dynamic, Manual

Initial State: The game is in Normal Mode.

Input: The user will hold down the Resign button for ENDTIME seconds.

Output: The game state will change to the Game Inactive State.

Test Case Derivation: The game shall be in the Game Inactive State due to the Resign button being pressed.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state is in the Game Inactive State.

3. NB-3

Type: Functional, Dynamic, Manual

Initial State: The game is in Normal Mode.

Input: Both users will press the Draw button within an interval of ENDTIME seconds each located on their side of the board.

Output: The game state will change to the Game Inactive State.

Test Case Derivation: The game shall be in the Game Inactive State due to the Draw buttons being pressed.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state is in the Game Inactive State.

4. ND-1

Type: Functional, Dynamic, Manual

Initial State: The game is in Normal Mode.

Input: The system shall send the micro-controller output over Bluetooth as an input to the web application.

Output: The web application shall receive the micro-controller output sent over Bluetooth.

Test Case Derivation: The web application should receive new information regarding the board state over Bluetooth.

How test will be performed: The function that checks to see if any information is being transmitted from the micro-controller will be run using the appropriate inputs. After it has ran we will check to see if the appropriate information has been received.

5. NA-1

Type: Functional, Dynamic, Manual

Initial State: The game is in Normal Mode.

Input: The web application shall receive the micro-controller output sent over Bluetooth.

Output: The web application will display the updated game board configuration with the data of the previous move.

Test Case Derivation: The web application should update the board configuration after receiving new information about the board state.

How test will be performed: The function that updates the game board configuration will be run using the appropriate inputs. After it has ran we will check to see if the board state has been updated.

6. NA-2

Type: Functional, Dynamic, Manual

Initial State: The game is in Normal Mode.

Input: The game has been terminated through method of stalemate, checkmate, resignation, or draw.

Output: The web application will display a message with the method of game termination and the system shall change to the Game Inactive State.

Test Case Derivation: The web application should display a message signifying user of the method of game termination and the game should modify state if the game has ended.

How test will be performed: The function that checks to see if any of the game termination method in effect will be run using the appropriate inputs. After it has ran we will output the termination method and change the game state to the Game Inactive State.

5.1.4 Engine Mode

1. EB-1

Type: Functional, Dynamic, Manual

Initial State: The game is in Engine Mode.

Input: A piece has been moved to a square.

Output: The system stores the position, colour, and type of piece in the micro-controller.

Test Case Derivation: The system should contain the position, colour, and type in the micro-controller after a piece has been moved to a square.

How test will be performed: The function that accesses the micro-controller will be run using the appropriate inputs. After it has ran we will check to see if the position, colour, and type of piece are stored in the micro-controller.

2. EB-2

Type: Functional, Dynamic, Manual

Initial State: The game is in Engine Mode.

Input: The user will hold down the Resign button for ENDTIME seconds.

Output: The game state will change to the Game Inactive State.

Test Case Derivation: The game shall be in the Game Inactive State due to the Resign button being pressed for ENDTIME seconds, signifying that the game should end.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state is in the Game Inactive State.

3. EB-3

Type: Functional, Dynamic, Manual

Initial State: The game is in Engine Mode.

Input: Both users will press the Draw button within an interval of ENDTIME seconds each located on their side of the board.

Output: The game state will change to the Game Inactive State.

Test Case Derivation: The game shall be in the Game Inactive State due to the Draw buttons being pressed.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state is in the Game Inactive State.

4. EB-4

Type: Functional, Dynamic, Manual

Initial State: The game is in Engine Mode.

Input: The top engine moves are transmitted to the LCD display from the web application.

Output: The LCD display shows the top engine moves.

Test Case Derivation: The top engine moves need to be transmitted to the LCD display in order to show both users the best moves for a position.

How test will be performed: The function that displays characters on the LCD display will be run using the appropriate inputs. After it has ran we will check to see if the requested characters are correctly displayed.

5. ED-1

Type: Functional, Dynamic, Manual

Initial State: The game is in Engine Mode.

Input: The system shall send the micro-controller output over Bluetooth as an input to the web application.

Output: The web application shall receive the micro-controller output sent over Bluetooth.

Test Case Derivation: The web application should receive new information regarding the board state over Bluetooth.

How test will be performed: The function that checks to see if any information is being transmitted from the micro-controller will be run

using the appropriate inputs. After it has ran we will check to see if the appropriate information has been received.

6. ED-2

Type: Functional, Dynamic, Manual

Initial State: The game is in Engine Mode.

Input: The system shall send the web application engine moves to the LCD display over Bluetooth.

Output: The LCD display shall receive the web application output sent over Bluetooth.

Test Case Derivation: The LCD display should receive the top engine moves over Bluetooth.

How test will be performed: The function that checks to see if any information is being transmitted from the web application using the appropriate inputs. After it has ran we will check to see if the appropriate information has been received by the LCD display.

7. EA-1

Type: Functional, Dynamic, Manual

Initial State: The game is in Engine Mode.

Input: The web application shall receive the micro-controller output sent over Bluetooth.

Output: The web application will display the updated game board configuration with the data of the previous move

Test Case Derivation: The web application should update the board configuration after receiving new information about the board state.

How test will be performed: The function that updates the game board configuration will be run using the appropriate inputs. After it has ran we will check to see if the board state has been updated.

8. EA-2

Type: Functional, Dynamic, Manual

Initial State: The game is in Engine Mode.

Input: The system shall use the chess engine to evaluate the position and calculate the best engine moves.

Output: The system shall display the calculated engine moves on the web application.

Test Case Derivation: The chess engine should update the board configuration after receiving new information about the board state.

How test will be performed: The function that calculates the engine moves will be run using the appropriate inputs. After it has ran we will check to see if the correct engine moves are played by comparing the results to the identical engine on an online platform.

9. EA-3

Type: Functional, Dynamic, Manual

Initial State: The game is in Engine Mode.

Input: The game has been terminated calculated stalemate or checkmate, or user-selected resignation or draw.

Output: The web application will display a message with the method of game termination and the system shall change to the Game Inactive State.

Test Case Derivation: The web application should display a message signifying user of the method of game termination and the game should modify state if the game has ended.

How test will be performed: The function that checks to see if any of the game termination methods are in effect will be run using the appropriate inputs. After it has ran we will out the termination method of change the game state to the Game Inactive State.

5.1.5 Beginner Mode

1. BB-1

Type: Functional, Dynamic, Manual

Initial State: The game is in Beginner Mode.

Input: A piece has been moved to a square.

Output: The system stores the position, colour, and type of piece in the micro-controller.

Test Case Derivation: The system should contain the position, colour, and type in the micro-controller after a piece has been moved to a square.

How test will be performed: The function that accesses the micro-controller will be run using the appropriate inputs. After it has ran we will check to see if the position, colour, and type of piece are stored in the micro-controller.

2. BB-2

Type: Functional, Dynamic, Manual

Initial State: The game is in Beginner Mode.

Input: The user picks up a piece.

Output: User views all legal moves with green LED lights on valid squares.

Test Case Derivation: This is needed to ensure users provide legal inputs to the system, and also provide visual feedback to accelerate learning.

How test will be performed: The function that accesses the legal moves and LEDs will be run using the appropriate inputs. After it has ran we will check to see if the correct legal moves are shown with green LED lights.

3. BB-3

Type: Functional, Dynamic, Manual

Initial State: The game is in Beginner Mode.

Input: The player makes an illegal move.

Output: The tile that the piece is moved onto will display a red LED light.

Test Case Derivation: This is needed to prevent users from providing illegal inputs to the system to minimize errors, and also provide visual feedback to accelerate learning.

How test will be performed: The function that accesses the legal moves and LEDs will be run using the appropriate inputs. After it has ran we will display a red LED light if the output is not within the legal moves.

4. BB-4

Type: Functional, Dynamic, Manual

Initial State: The game is in Beginner Mode.

Input: The user will hold down the Resign button for ENDTIME seconds.

Output: The game state will change to the Game Inactive State.

Test Case Derivation: The game shall be in the Game Inactive State due to the Resign button being pressed.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state is in the Game Inactive State.

5. BB-5

Type: Functional, Dynamic, Manual

Initial State: The game is in Beginner Mode.

Input: Both users will press the Draw button within an interval of ENDTIME seconds each located on their side of the board.

Output: The game state will change to the Game Inactive State.

Test Case Derivation: The game shall be in the Game Inactive State due to the Draw buttons being pressed.

How test will be performed: The function that changes the game state will be run using the appropriate inputs. After it has ran we will check to see if the game state is in the Game Inactive State.

6. BD-1

Type: Functional, Dynamic, Manual

Initial State: The game is in Beginner Mode.

Input: The system shall send the micro-controller output over Bluetooth as an input to the web application.

Output: The web application shall receive the micro-controller output sent over Bluetooth.

Test Case Derivation: The web application should receive new information regarding the board state over Bluetooth.

How test will be performed: The function that checks to see if any information is being transmitted from the micro-controller will be run using the appropriate inputs. After it has ran we will check to see if the appropriate information has been received.

7. BA-1

Type: Functional, Dynamic, Manual

Initial State: The game is in Beginner Mode.

Input: The user clicks to view the instructions regarding the rules of chess.

Output: The web application displays a detailed set of rules on how to play chess.

Test Case Derivation: TIt is necessary for users to have a set of instructions as reference while using the application in Beginner Mode.

How test will be performed: The function that displays the rules will be run using the appropriate inputs. After it has ran we will check to see if the web application is displaying the rules.

8. BA-2

Type: Functional, Dynamic, Manual

Initial State: The game is in Beginner Mode.

Input: The web application shall receive the micro-controller output sent over Bluetooth.

Output: The web application will display the updated game board configuration with the data of the previous move

Test Case Derivation: The web application should update the board configuration after receiving new information about the board state.

How test will be performed: The function that updates the game board configuration will be run using the appropriate inputs. After it has ran we will check to see if the board state has been updated.

5.2 Tests for Nonfunctional Requirements

5.2.1 Look and Feel

Style

1. NFT-1

Type: Structural, Static, Manual

Initial State: Users have not seen the product before, and the product is in its initial game state.

Input/Condition: Users are asked to identify the product.

Output/Result: The majority of users are able to successfully identify the product as a chess set without any outside assistance within 10 seconds.

How test will be performed: A test group of people who do not play chess regularly are asked to identify the product immediately after it is revealed to them. The time it takes for them to identify the product will be recorded. The subjects must identify the product as a chess set within 10 seconds or less, averaged over the number of people in the test group.

5.2.2 Usability and Humanity

Learnability

1. NFT-2

Type: Structural, Static, Manual

Initial State: Product is in normal mode, a game has started, and the users have not interacted with the product before.

Input/Condition: Users are asked to use the product and move one specified piece from one square to another specified square on the board.

Output/Result: The majority of users understand which piece they moved and to where, and are able to identify that the web application has reflected their move in the virtual model within 30 seconds of studying the visual representation of the board state.

How test will be performed: A test group of people who do not play chess regularly are asked to move pieces on the chessboard. They are then asked to identify the move they just made as reflected in the web application model. The subjects must identify that the piece they moved on the board has also been moved on the web application's virtual model within 30 seconds or less, averaged over the number of people in the test group.

2. NFT-3

Type: Functional, Dynamic, Manual, Static etc.

Initial State: The product shall be representing the state of the game that is in progress. The pieces shall be in a legal position according to the rules of chess. The pieces shall not all be in their starting positions, and there is at least one of each type of piece (pawn, knight, bishop, rook, queen, king) on the board.

Input: Users are asked to identify the names of different pieces and squares based on their visual appearance in both the physical product and the web application.

Output: The majority of users are able to identify the names of pieces and squares based on their likeliness to historically used symbols and shapes.

How test will be performed: A test group of people who have played chess in the past or play chess regularly are asked to identify each of the pieces and squares from an in-progress game of chess using the system. The justification for this is to avoid piece identification based on their

starting positions. The majority of the group should be able to visually identify every piece and square within 2 minutes of seeing the position for the first time.

5.2.3 Performance

Speed and Latency

1. NFT-4

Type: Structural, Static, Manual

Initial State: The product is in normal mode, and a game has started.

Input/Condition: Users are asked to pick up a piece and suspend it midair without placing it down.

Output/Result: The board shall visually indicate where the held piece is able to move according to the rules of chess within a specific time frame.

How test will be performed: A test group of people who have played chess in the past or play chess regularly are asked to pick up a specific piece and hold it. The system will give visual indicators of where the held piece is able to move according to the rules of chess. The time between when they pick up the piece and when the visual response occurs is measured and recorded. This process is repeated 5 times per user. The individual and average times are recorded. The response times are then averaged over the entire test group. The average response time of the entire test group must be less than 0.5 seconds.

2. NFT-5

Type: Structural, Static, Manual

Initial State: The results of the previous test, NFT-4, have been measured and recorded.

Input/Condition: The results of NFT-4.

Output/Result: The maximum recorded time of any individual response is within a specific time frame.

How test will be performed: The times measured in the previous test, NFT-4, will be inspected. The maximum recorded individual time must be less than 1 second.

3. NFT-6

Type: Structural, Static, Manual

Initial State: The product is in normal mode, and a game has started.

Input/Condition: Users are asked to pick up a piece and legally move it to a square according to the rules of chess.

Output/Result: The web application shall reflect their move in the virtual model within a specific time frame.

How test will be performed: A test group of people who have played chess in the past or play chess regularly are asked to pick up a specific piece and legally move it to another square according to the rules of chess. The web application will reflect their move in the virtual model. The time between when they place down the piece and when the web application response occurs is measured and recorded. This process is repeated 5 times per user. The individual and average times are recorded. The response times are then averaged over the entire test group. The average response time of the entire test group must be less than 2 seconds.

4. NFT-7

Type: Structural, Static, Manual

Initial State: The results of the previous test, NFT-6, have been measured and recorded.

Input/Condition: The results of NFT-6.

Output/Result: The maximum recorded time of any individual response is within a specific time frame.

How test will be performed: The times measured in the previous test, NFT-6, will be inspected. The maximum recorded individual time must be less than 5 seconds.

Health and Safety

1. NFT-8

Type: Structural, Static, Manual

Initial State: The product is in normal mode, and a game has started.

Input/Condition: 10 wires are chosen as a sample.

Output/Result: The maximum power on any single wire shall be within the required limit.

How test will be performed: A sample of 10 wires are chosen arbitrarily from across the entire system. The voltage and amperage of each wire in the sample are measured and recorded. The power shall then be calculated and recorded. The maximum power of any wire in the sample must not exceed the safe limits determined in the Canadian Electrical Code [CSA \(2021\)](#).

Precision and Accuracy

1. NFT-9

Type: Structural, Static, Manual

Initial State: The product is in the initial game state.

Input/Condition: Users are instructed to play a full game of chess using the Chess Connect system.

Output/Result: The web application will properly reflect the moves made on the physical product the majority of the time.

How test will be performed: A test group of people who have played chess in the past or play chess regularly are asked to play a full game of chess. Their moves and the web application response will be recorded and compared against each other. The number of discrepancies between the physical moves and moves made on the web application will be recorded. The number of discrepancies averaged over the entire test group must be less than or equal to 1.

Capacity

1. NFT-10

Type: Structural, Static, Manual

Initial State: The product is in the initial game state and is in engine mode.

Input/Condition: Moves are made until the game state is in one of a set of predetermined computationally complicated chess positions.

Output/Result: The level of memory used by the web application shall be no more than 1 Gigabyte (GB) at any measured point.

How test will be performed: Moves will be made until the game state is in one of a set of predetermined computationally complicated chess positions. The engine will then be using the maximum amount of memory to compute the best possible moves for the position. The amount of memory used will be measured and recorded using windows task manager. The amount of memory must never exceed 1 GB at any measured point.

5.2.4 Security

Integrity

1. NFT-11

Type: Structural, Static, Manual

Initial State: The product is in normal mode and a chess game is in progress on the system.

Input/Condition: The Bluetooth connection is severed between the web application and the product.

Output/Result: The web application indicates that the Bluetooth connection has been lost.

How test will be performed: A game of chess is being played when the Bluetooth option is switched off (either from the server or the hardware), severing the connection. The web application must display an alert that the Bluetooth connection has been lost.

1. NFT-12

Type: Structural, Static, Manual

Initial State: The product is in normal mode and a chess game is in progress on the system.

Input/Condition: The power connection to the system is severed.

Output/Result: The system stores the game state in local memory until power is restored.

How test will be performed: A game of chess is being played when the power is switched off. The power is then restored after 5 or more seconds. A single move is made and the state of the game is tested against the web application. The state of the game should be unchanged from before power was lost.

1. NFT-13

Type: Privacy, Static, Manual

Initial State: The product is in any mode and a chess game is completed on the system.

Input/Condition: The game is reset and re-enters the initial state.

Output/Result: The system has no memory of the previous user or game played.

How test will be performed: A game of chess is being played when the end of the game is reached (checkmate, draw, stalemate and resign will be tested). A member of our team will inspect the data on the server and verify that there is nothing stored in memory from the previous game.

1. NFT-14

Type: Security, Static, Manual

Initial State: The product source code is on GitHub, and security settings will be active so only members of the Chess Connect organization can make changes to the code.

Input/Condition: A member and a non-member account will attempt to modify the source code.

Output/Result: The non-member will be prevented from modifying the code, while the member will be able to.

How test will be performed: A team member will create a dummy account to attempt to change the source code. He will then use his actual account to modify the same code. GitHub security settings will be checked to verify that the non-member attempt was blocked.

1. NFT-15

Type: Continuous, Manual

Initial State: The documentation for the product will contain requirements to be matched to the VnV Plan.

Input/Condition: Feedback will be given on the product requirements.

Output/Result: Requirements will be updated according to the feedback recieved, and checked to ensure complete requirement satisfaction.

How test will be performed: All initial requirements will be traced and checked in the VnV Plan. New requirements from subsequent rounds of feedback recieved will be included in an ongoing basis, and verified by a member of the Chess Connectteam.

5.3 Traceability Between Test Cases and Requirements

Test	Requirement
GA-1	GA1
GA-2	GA2
GA-3	GA3
GA-4	GA6
GA-5	GA7
GI-1	GI1
GI-2	GI2
GI-3	GI3
GI-4	GI4
GI-5	GI5, GI6
NB-1	NB1
NB-2	NB2
NB-3	NB3
ND-1	ND1
NA-1	NA1, NA2
NA-2	NA3
EB-1	EB1
EB-2	EB2

EB-3	EB3
EB-4	EB4
ED-1	ED1
ED-2	ED2
EA-1	EA1, EA2
EA-2	EA3, EA4, EA5
EA-3	EA6
BB-1	BB1
BB-2	BB2
BB-3	BB3
BB-4	BB4
BB-5	BB5
BD-1	BD1
BA-1	BA1
BA-2	BA2
NFT-1	LF3
NFT-2	UH5
NFT-3	UH6
NFT-4	PR1
NFT-5	PR2
NFT-6	PR3
NFT-7	PR4
NFT-8	PR6, SR1, SR2
NFT-9	PR7
NFT-10	PR10
NFT-11	IR3
NFT-12	IR2
NFT-13	IR1, PVR1
NFT-14	ACR1
NFT-15	AUR1

Table 4: Traceability Matrix

References

CSA. *Canadian Electrical Code*. CSA Group, 2021.

Appendix — Reflection

The information in this section will be used to evaluate the team members on the graduate attribute of Lifelong Learning. Please answer the following questions:

1. **Arduino Zero Built-in Debugger Interface** is necessary to simulate and test the arduino code on the microcontroller. Learning the software requires reading documentation for installing and operating the debugger. As well, interpreting the outputs from the debugger requires practice. Joshua Chapman will be taking this responsibility.
2. **React Testing Library** is used for testing web application code. All coding in the web application will be done using javascript and react. Documentation for using the library will be read and experimented to develop a thorough understanding. Rupinder Nagra and Jonathan Cels will be taking this responsibility.
3. **Pytest** is used to perform unit tests on python code for custom microcontroller programming and bluetooth connection. Documentation to use the desired functionality will be read. Additionally, a learning period will be required to properly learn the outputs of the unit tester. Jonathan Cels and Arsheep Aujla will be taking this responsibility.
4. **Flake8** simplifies the Github workflow by performing non-blocking checks on integrated code. Integrating it into Github will require reading documentation and practicing before important deadlines. Alexander Van Kralingen will be taking this responsibility.