System Test Plan

For

NASA Vestibular Chair

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1. Introduction

1.1 Purpose

This document is a test plan for the NASA Vestibular Chair System, produced by the system testing team. It describes the testing strategy and approach to testing the team will use to verify that the application meets the established requirements of the product owner.

1.2 Objectives

- Meets the requirements, and specifications set by the product owner.
- Satisfies the needed safety requirements.
- Performs within expected measures with little error.

2. Functional Scope

The Modules in the scope of testing for the NASA Vestibular Chair System testing are mentioned in the document attached in the following path:

1. The System Requirements Specification document:
   https://github.com/prowl107/NASA-Vestibular-Chair/blob/main/Documentation/SRS/System%20Requirements%20Specification%20V2.pdf

NOTE: Version 3 of the SRS is currently in development and the link will be updated to reflect the changes upon completion.

2. Section 3.1 of this document

3. Standard Operating Procedures for Proctors and Operators:
   https://github.com/prowl107/NASA-Vestibular-Chair/blob/main/Documentation/User%20Manual/NASAChair_User_Manual.pdf

3. Overall Strategy and Approach

3.1 Testing Strategy

The NASA Vestibular Chair testing strategy will include testing the functionality of all items included in section 2. Tested items include the following:

1. Transmitting commands to the motor controller to test the functionality of the chair in relation to its rotational speed (e.g., increase the voltage sent to the chair by a rate of 0.05V per second, decrease the voltage sent to the chair by a rate of 0.05V per second.)

2. Mechanical kill switch operation to ensure power delivery is immediately suspended.

3. Soft switches to ensure the chair slows down gradually but not abruptly causing damage to the patient (e.g., removing power at a rate of 0.05V per second)

4. Nominal test sequence to raise the motor to a speed within 100 degrees per second and allow the chair to free coast down to an idle state

5. Bi-directional input (buttons) to allow the user to indicate the perceived spin direction to the system as either “left”, “right”, “both”, or none.

3.1.1 Function Testing

Test Objective: Ensure the controller module can properly provide power to the chair, as well as stop it with its kill switch. This includes both the soft switches and the mechanical kill switch.

3.1.1.1 Mechanical Hard/Kill Switch Testing:

1. 1. Wire the controller module to the vestibular chair and initiate a sequence that will provide voltage to rotate the chair.

1. 2. During the test, press/depress the mechanical hard kill switch and measure the input voltage on the chair’s power terminals.

1. 3. Observe the motor behavior of the chair to ensure it is in a free coast state.

3.1.1.2 Soft Switch Testing:

2. 1. Wire the controller module to the vestibular chair and initiate a sequence that will provide voltage to rotate the chair.

2. 2. During the test, press/depress the soft kill switch and measure the input voltage on the chair’s power terminals.

2. 3. Observe the motor behavior of the chair to ensure that it reaches 0 rpm in the specified amount of time.

Completion Criteria: In all test cases the controller can provide power to the chair to have it move, and the kill switch can kill power to the chair and or bring it to an idle state.

3.1.2 Data Testing

Test Objective: Ensure the data that is collected is collected properly, able to be exported in the correct format, and displayable.

Technique:

1. Start the web interface
2. Initialize the control module as the receiver and the patient remote control as the sender.
3. Wait for an established connection to be made before proceeding.
4. Begin data transmission from the remote to the control module.
5. The control module will receive and store all packets from the receiver.
6. The control module will send the collected data to the web interface.
7. The web interface shall display the data collected from the receiver.

Completion Criteria: In all test cases, the proper data collection is displayed, and all measured values are accurate.

3.1.3 Performance Testing

Test Objective: Ensure the chair can ramp up to the specified RPM, coast, and then lower its speed until it stops moving.

Technique: Write test cases using the controller module that specifies the RPM value and measures with a tachometer to determine if the chair is spinning at the correct speed.

Completion Criteria: In all test cases, the chair reaches the RPM set through the controller and manages to coast to a stop.

3.2 System Testing Entrance Criteria

In order to start system testing, the testing readiness can be classified under usability testing, functional testing, and data testing.

3.3 Testing Types

3.3.1 Usability Testing

The user interface will be tested for ease of use as well as how accurately it is able to perform the actions specified by the user in relation to the controller itself as well as the vestibular chair. This is done through stress testing of the controller, as it is the focal point of user interaction with the rest of the system.

System Requirements Specification, SYS-5:” The system shall have a "hard" mechanical kill switch that will disable power delivery to the chair.

System Requirements Specification, SYS-20:” The system shall support user input from a bi-directional control interface.”

System Requirements Specification, SYS-25:” The proctor shall only be able to actuate the chair

or start a test after a unique button/switch is pressed (arming switch)

System Requirements Specification**,** SYS-30:" The web interface shall allow the operator to add different test sequences."

System Requirements Specification**,** SYS-58**:"** The web interface shall display stored test sequences from a dropdown menu."

3.3.2 Data Testing

The data will be tested for the correctness of measurement based on known inputs, as well as its ability to display properly on the display that will be a part of the controller module. Additionally, this presents criteria to evaluate the functionality of the patient's remote device.

System Requirements Specification**,** SYS-8**:"** The system shall record the chair's current position (steady state)."

System Requirements Specification, SYS-9:" The system shall record the desired rpm set by the proctor."

System Requirements Specification**,** SYS-10**:"** The system shall record the rpm that the chair is currently spinning at."

System Requirements Specification, SYS-11: "The system shall record the time elapsed during the current test sequence."

System Requirements Specification**,** SYS-12:" When the user indicates via the bi-directional control method, the system shall record the total time the user indicates they are spinning."

System Requirements Specification**,** SYS-13:" When the user indicates via the bi-directional control method, the system shall record the direction they think they are spinning in."

System Requirements Specification**,** SYS-16:" The system shall record acceleration data."

System Requirements Specification**,** SYS-17:" The system shall record tachometer data."

System Requirements Specification, SYS-68:" The system shall record the time when the chair comes to a complete stop after the trial duration has elapsed."

System Requirements Specification, SYS-69:" The system shall continue to record data until the proctor has signaled the end of the test."

3.3.3 Functional Testing

The functionality of the device will be tested for the chair's ability to function correctly as intended and indicated by the user. This includes its ability to spin at a speed, the proctor defines, the controller's ability to function properly in relation to data collection, and its ability to provide correct instructions for the functionality of the chair such as setting its speed and direction of rotation.

System Requirements Specification**,** SYS-1**:"** The system shall allow the chair to spin up to a specified RPM determined by the proctor".

System Requirements Specification**,** SYS-2**:"** After a specified duration set by the operator/proctor, the chair should enter a free coast state."

System Requirements Specification**,** SYS-4**:"** The system shall not exceed 100 degrees per second (1 revolution every 3 seconds) at any point during its operation."

System Requirements Specification**,** SYS-23**:"** The system must interface with a wireless bi-directional controller such as a joystick or button."

System Requirements Specification**,** SYS-70**:"** The control module shall maintain wireless communication with the patient remote throughout the entirety of each trial."

3.4 Suspension Criteria and Resumption Requirements

This section will specify the criteria that will be used to suspend all or a portion of the testing activities on the items associated with this test plan.

3.4.1 Suspension Criteria

- If the controller causes too large of an output of power to the chair resulting in the motor spinning higher than the specified limit of 100 degrees per second.
- If the mechanical kill switch fails to cut power to the chair while it rotates.
- Non-deterministic transitions between system states

3.4.2 Resumption Requirements

Resumption of testing will occur when the mechanical kill switch is wired to correctly kill the power, or when an additional switch is used to perform the same function given a malfunction of the initial switch.

4. Execution Plan

4.1 Execution Plan

The test plan for the NASA Vestibular Chair is as follows:

Requirement (From SRS)	Test Case Identifier	Input	Expected Behavior	Pass / Fail
SYS-1: The system shall allow the chair to spin up to a specified RPM determined by the proctor	1.1	The proctor inputs specified RPM for the chair to spin at.	The chair spins at the RPM determined by the proctor without much deviation.	Pass*
SYS-24: The proctor shall be able to stop the currently executing test by pressing the "soft kill switch"	2.1	1. The proctor presses the soft kill switch during a currently running test before the	The chair will slow to a stop faster than it would if the speed was manually turned down.	Pass

		target RPM is reached. 2. The proctor pressed the soft kill switch after the target RPM has been reached.		
SYS-51**:** The proctor shall be able to terminate power delivery to the chair by pressing a mechanical switch	3.1	The proctor presses the mechanical kill switch on the controller.	The chair will enter a free coast state and gradually slow down to 0 RPM. The control module should remain powered	Pass
SYS-8: The system shall record the chair's current position (steady state).	4.1	1. The target RPM for the test 2. Measurements of the chair's current speed with timestamps	The chair's rotational position will be displayed to the proctor.	Pass
SYS-10: The system shall record the rpm that the chair is currently spinning.	5.1	Tachometer readings collected from the chair	1. The chair's rotational speed will be output to the proctor. 2. The chair's rotational speed will be stored temporarily in a non-volatile storage location.	Pass
SYS-12: When the user indicates via the bi-directional control method, the system shall record the total time the user indicated they are spinning	6.1	1. Continuous signals of the patient interacting with the wireless joystick regardless of the direction 2. Timestamps of each signal sent to the control module	1. The joystick reading will be output to the proctor indicating when it is used. 2. The chair's rotational speed will be stored temporarily in a non-volatile storage location	Pass
SYS-20: The system shall support user	7.1	Presence of a joystick that	The joystick transmits to the controller	Pass

input from a bi-directional human input device		interfaces with the controller.	properly.	
SYS-21: The system shall allow the user to indicate what direction they are spinning via a bi-directional control method	7.2	Presence of a joystick that interfaces with the controller	The user's feedback from the input device will be displayed accurately after the test has been completed	Pass
SYS-22: The system shall record intermediate values for the direction indicated	7.3	Presence of a joystick that interfaces with the controller	The chair's rotational speed will be stored temporarily in a non-volatile storage location	Pass
SYS-23: The system shall interface with a wireless bi-directional human input device such as a joystick or button	7.4	Presence of a joystick that interfaces with the controller.	The joystick interfaces with the controller correctly.	Pass
SYS-27: The proctor shall set the duration of the test either via the web interface or the controller module	8.1	Proctor utilizes an interface to select a test sequence or input parameters.	The chair will begin moving according to the parameters set by the proctor.	Pass
SYS-15: The system shall have the ability to export data in a human-readable format	9.1	Collection of sample data from a running or test or randomly generated data in an equivalent format	1. The processed data will be displayed to the user via the web interface 2. From the web interface, the proctor can export the data in a CSV file format 3. The generated file is viewable without any abnormalities	Pass
SYS-19: The system shall record data at a sample rate of at least 20 HZ	10.1	1. Collection of sample data from a running or test or randomly generated data from a HITL sequence.	Visual inspection of data and the respective timestamp will demonstrate that there are at least 20 samples taken per second.	Pass

		2. All data will have a timestamp associated		
SYS-33: The web interface shall not execute any commands unless connection with the control module has been established	11.1	A hardware connection between the control module and host PC (wire, serial-to-USB adapter, etc.)	The web waits for an acknowledgment from the control module before allowing any test or commands to be executed	Currently under test
SYS-30: The web interface shall allow the operator to add different test sequences	12.1	Proctor inputs parameters into web interface.	Different test sequences are stored in the web interface.	(Deprecated)
HDW-11: The physical switch shall not disconnect power to the control module	13.1	A test setup consisting of a DC power supply wired to the motor controller, vestibular chair, and control module, with the physical switch to toggle power	1. Once the mechanical switch is pressed/depressed, the power should be disconnected. The chair should stop moving 2. The control module should still be powered which can be verified by observing the onboard LEDs	Pass
SYS-28: The proctor shall only be able to actuate the chair or start a test after a unique button/switch is pressed (arming switch)	15.1	1. A connection was established between the host PC and the controller module 2. Control module setup integrated with the vestibular chair	1. While the proctor is configuring the test, there will be no movement from the chair 2. The on-screen button for starting the test will be disabled until the arming switch has been enabled	Pass

NOTE: The test for SYS-1 does pass. However, it is based on speeds when a load is not applied to the chair. However, the product owner is aware of the behavior and feels that the current output will suffice. Once the desired speed has been reached, it does not deviate from the target.

NOTE: The test for SYS-10 does pass. The value is recorded with the analog value from the tachometer with a 12-bit resolution such that 0° corresponds to a value of 0 and 360° corresponds to 4095.

NOTE: The test for SYS-30 is marked as deprecated. After discussions with our shareholders, it was determined that this feature is no longer needed and consequently the exclusion of the test. The listing will remain in the test plan for record keeping.

5. Traceability Matrix & Defect Tracking

5.1 Traceability Matrix

List of requirements, corresponding test cases

***Requirement* CRITICAL**: System Requirements Specification**,** SYS-1: "The system shall allow the chair to spin up to a specified RPM determined by the proctor."

Test Cases*:* Check for accurate RPM of the chair with a tachometer compared to proctor set value.

***Requirement* CRITICAL**: System Requirements Specification**, S**YS-43**: "**If the controller detects a soft kill switch was pressed, the controller shall bring the chair to a speed of 0 RPM at a gradual rate."

Test Cases*:* Check that the kill switch cuts power to the chair and lets it free spin.

***Requirement* CRITICAL**: System Requirements Specification**,** SYS-51**:** "The proctor shall be able to terminate power delivery to the chair by pressing a mechanical switch."

Test Cases*:* Check that the kill switch cuts power to the chair immediately.

***Requirement* MEDIUM**: System Requirements Specification**,** SYS-8: "The system shall record chair's current position (steady state)."

Test Cases*:* Check that the sensors correctly measure the chair's position.

***Requirement* MEDIUM**: System Requirements Specification**,** SYS-10: "The system shall record the rpm that the chair is currently spinning at."

Test Cases*:* Check for RPM measurement output using tachometer.

***Requirement* MEDIUM**: System Requirements Specification**,** SYS-14: "When the user indicates via the bi-directional control method, the system shall record timestamps of when the button is triggered."

Test Cases*:* Check that buttons on the handheld controller transmits properly to controller module.

***Requirement* CRITICAL**: System Requirements Specification**,** SYS-20: "The system shall support user input from a bi-directional control interface."

Test Cases*:*

***Requirement* CRITICAL**: System Requirements Specification**,** SYS-23**:** "The system must interface with a wireless bi-directional controller such as a joystick or button."

Test Cases*:*

***Requirement* MEDIUM**: System Requirements Specification**,** SYS-30: "The web interface shall allow the operator to add different test sequences."

Test Cases*:* Check that the operator is allowed to utilize multiple test cases.

***Requirement* MEDIUM**: System Requirements Specification**,** SYS-55: "The web interface shall feature a unique button to select the test sequence."

Test Cases*:* Check that the software defined button will connect to the correct sequence.

5.2 Defect Severity Definitions

Critical	The defect causes a catastrophic or severe error that results in major problems and the functionality rendered is unavailable to the user. A manual procedure cannot be either implemented or a high effort is required to remedy the defect. Examples of a critical defect are as follows: • System abends • RPM limit is exceeded • Data is corrupted or cannot post to the database
Medium	A defect that does not seriously impair system function can be categorized as a medium Defect. A manual procedure requiring medium effort can be implemented to remedy the defect. Examples of a medium defect are as follows: • Form navigation is incorrect • Field labels are not consistent with global terminology
Low	The defect is cosmetic or has little to no impact on system functionality. A manual procedure requiring low effort can be implemented to remedy the defect. Examples of a low defect are as follows: • Repositioning of fields on screens • The text font on reports is incorrect

6. Environment

6.1 Environment

- To conduct the testing, the tester needs to have the following:
    1. Access to the NASA Vestibular chair
    2. Access to the controller of the chair
    3. Access to the selected power supply or equivalent
    4. Access to the patient remote device

7. Assumptions

This section details specific assumptions that are made throughout the project

- No individual is sitting in the NASA Vestibular Chair
- The power supply connected to the controller and chair does not output higher than 12V

8. Risks and Contingencies

Some risks involved with testing the NASA Vestibular Chair involve the possibility of spinning the chair too fast. This consideration is made because if the controller supplies too high of a voltage, the chair could risk falling over or hurting the individual sitting in it. The contingency in place to prevent this is the code built into the controller to prevent the voltage from being supplied at a value that would cause the rotational speed of the chair to exceed 100 degrees per second, as well as a mechanical kill switch that will be built into the controller to shut off power to the chair if it begins to spin too fast.

Another potential risk involved with the testing comes in the form of loss of information between the controller and analog components of the chair. Since the components within the NASA Vestibular Chair are mostly analog, there is a chance of loss of data between the components present in the internal hardware and those in the controller. A contingency for this is the inclusion of digital components within the controller, to have two forms of communication with the internal hardware of the chair as a backup in case one fails.

Risk #	Risk	Impact	Contingency
1	Chair Spins too Fast	High	Code built into the controller to prevent the voltage from being supplied at a value that would cause the rotational speed of the chair to exceed 100 degrees per second, as well as a mechanical kill switch which will be built into the controller to shut off power to the chair if it begins to spin too fast UPDATE: From testing, it was observed that the chair could be physically stopped by holding it in place in the event of an emergency
2	Information loss between controller and chair	High	Inclusion of digital components within the controller, to have two forms of communication with the internal hardware of the chair as a backup in case one fails

9. Appendices

None currently available