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# **System Requirements Specification for NASA Vestibular Chair**

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## Revision History

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V2 WIP	10/30/22	Update system requirements	0.11
V2	11/8/22	Version 2 release	0.2
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V3 Format Updates	12/9/22	Added more requirements, changed formatting	0.3
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## Introduction

This project is designed with the purpose of restoring functionality to the NASA Vestibular Chair. The device was originally used in the late 1960s to conduct experiments and trials for astronauts and pilots to assess vestibular ocular reflex suppression. The purpose of the restoration is to conduct trials to study vestibular system illusions.

The chair was actively involved in research at NASA and was recently acquired by Embry-Riddle Aeronautical University faculty. This project involves restoring its basic functionality and then adding software functionality to improve the ease of use.

### 1.1 Purpose

The purpose of this document is to describe the requirements and constraints for restoring and operating the refurbished NASA vestibular chair. This document consists of specifications regarding the chair itself, the interaction between software and hardware, interactions between intended users, and any safety or legal standards that must be adhered to.

### 1.2 Document Conventions

*Nothing to list at this time.*

### 1.3 Intended Audience and Reading Suggestions

The intended users of this product include aerospace physiology researchers, pilots, astronauts, astronaut candidates, and engineers. This document contains information regarding the requirements and general functionality of the restoration of the NASA vestibular chair.

### 1.4 Product Scope

When the chair was given to researchers at Embry-Riddle Aeronautical University, its functionality was unknown. The last time the chair was operated would have been at least 30 years ago. Furthermore, the original controller used has been lost and its whereabouts are unknown. However, thanks to external support, documentation from the manufacturers of the chair has been acquired which provided the starting point for this project. The goal of this project has been to analyze the current state of the chair, determine its state of functionality, resolve any mechanical abnormalities, and expand on its basic functionality.

The original purpose of this chair was to study vestibular illusions that occur from flight. Once the project has been completed, the chair will be used to conduct research trials into spatial disorientation.

### 1.5 References

No references at this time.

## **2. Overall Description**

Section 2 discusses the overall purpose of the product. Each section details a specific aspect of the project as follows:

- Section 2.1 – Product perspective
- Section 2.2 – Product functions
- Section 2.3 – User classes and characteristics
- Section 2.4 – Operating environment
- Section 2.5 – Design and implementation constraints
- Section 2.6 – User documentation
- Section 2.7 – Assumptions and dependencies

### **2.1 Product Perspective**

The original implementation of the vestibular chair relied on an external control interface/station where a user could send commands to the chair. The restored design will follow the same design with a host station displaying a web interface to allow for commands to be sent to a dedicated hardware controller. The commands are then processed by the dedicated hardware controller and the vestibular chair will execute the desired command.

The SRS will focus on the controller module and the web interface. The operations of these items are essential to the operation of the restored NASA vestibular chair.

#### **2.1.1 Controller Module**

The controller module is the dedicated hardware controller that processes commands, performs data acquisition, and communicates with the web interface. The controller module consists of an Adafruit Feather nRF52840 Express microcontroller, Pololu Simple Motor Controller G2, an LCD screen, and physical I/O devices including but not limited to buttons, and potentiometers. A dedicated hardware controller was implemented to establish a baseline for controlling the chair, prevent the scope of the web interface from exceeding the intended purpose, and to take advantage of the physical I/O devices. Without the dedicated hardware, the proctor would have to solely rely on the web interface and have no means to physically control the chair.

#### **2.1.2 Web Interface**

The web interface is intended for the proctor's use only. This item gives the proctor more functionality as it pertains to controlling the chair and running tests. With the web interface developed, the goal is to give the proctor the means to configure a test sequence, as well as start the test, and export the test data to a csv file, all without the need to use the physical I/O components.

### 2.1.3 Bi-Directional User Input Device

As requested for testing purposes, the user shall be given the ability to indicate the direction they think they are spinning throughout the test. The most efficient way this was deemed to be possible was a wireless bi-directional input. While the design becomes refined and adjusted, the core objectives are as follows: (1) give the user the ability to indicate what direction they think they are spinning (clockwise, counterclockwise, stationary), (2) send the aforementioned data to the controller module to be processed, (3) give the user the ability to stop the test in case of an emergency.

## 2.2 Product Functions

- Actuate the analog motors to spin the user at a specified rate
- Collect data from the on-board sensors and external peripherals
- Collect data from the user through the use of wireless peripherals
- Log all collected data in a human-readable format
- Manage and start test sequences from the web interface
- Stop the test in the event of an emergency

## 2.3 User Classes and Characteristics

### 2.3.1 Patient

The patient is the user who will sit in the chair and take part in the experiment(s). Their role is to indicate what direction they believe they are spinning in throughout the test. This is accomplished via a bi-directional input device in the form of a pair of buttons to indicate the direction. Furthermore, the user may also indicate when they are not spinning by not orienting the control interface in either direction.

### 2.3.2 Proctor

The proctor will be responsible for interacting with the web-based user interface. Additionally, they will be responsible for configuring, selecting, and executing the test sequence. As a safety precaution, the proctor will have the ability to press/depress the mechanical kill switch in the event of an emergency where the currently running test or sequence needs to be canceled immediately.

## 2.4 Design and Implementation Constraints

### 2.4.1 Design Constraints

- The system cannot operate at greater than 12v. Beyond this range introduces bodily harm to the patient.
- No one can be within the chair's range of motion or diameter during operation except the patient sitting in the chair.

### 2.4.2 Implementation Constraints

- Accelerometer data will be limited by the capability and resolution of the on-board accelerometer.
- Tachometer data will be limited by the capability and resolution of the onboard tachometer.
- Due to the chair spinning, a wired bi-directional input for the user is not feasible.
- Desired RPM is also dependent on the patient's weight and posture in the chair.

## 2.5 User Documentation

Vestibular Chair User Manual: [https://github.com/prowl107/NASA-Vestibular-Chair/blob/main/Documentation/User%20Manual/NASA\\_Chair\\_User\\_Manual.pdf](https://github.com/prowl107/NASA-Vestibular-Chair/blob/main/Documentation/User%20Manual/NASA_Chair_User_Manual.pdf)

## 2.6 Assumptions and Dependencies

Nothing to list at this time.

# 3. System Features

Section 3 covers information regarding the usage and core functionality of the system. Sections 3.1 outlines the motor control requirements. Section 3.2 details the data acquisition for the system. Section 4.3 outlines user input and feedback. Sections 4.4 and 4.5 outline the web interface and controller requirements respectively.

## 3.1 Chair/Motor Control

### 3.1.1 Description and Priority

The system must provide a reliable means to control the brushless motor built into the vestibular chair. This includes aspects such as bringing the chair to the desired speed and then gradually lowering the speed to 0 RPM when the test has completed, or an emergency has been detected.

### 3.1.2 Stimulus/Response Sequences

When the proctor arms the system and indicates that the test is ready to start, the chair should be rotating. At the end of the test sequence, the test should return to 0 RPM.

### 3.1.3 Functional Requirements

REQ ID	Requirement
SYS-1	The system shall allow the chair to spin up to a specified RPM determined by the proctor
SYS-2	After a specified duration set by the proctor, the chair shall enter a free coast state
SYS-3	The system shall adjust the voltage to the motors in response to the user's weight

	to maintain the desired rate/RPM
SYS-4	The system shall not exceed 100 degrees per second (1 revolution every 3 seconds) at any point during its operation
SYS-5	While the chair has not reached the target RPM during operation, the system shall gradually increase the speed by 1.15° degrees per second
SYS-6	If the chair reaches the target RPM, the system shall stop increasing the speed of the chair.
SYS-7	The chair shall not spin faster than the target RPM under any circumstance
SYS-70	The control module shall maintain wireless communication with the patient remote throughout the entirety of each trial

NOTE: Target RPM is set by the proctor during the setup phase of operation.

## 3.2 Data Acquisition

### 3.2.1 Description and Priority

Acquiring data for analysis is an objective of this project as well. The system must record multiple pieces of data and display the information to the proctor. Furthermore, the data must be sampled at a fast enough rate to generate an accurate set of data with little error. This data should be viewable via the web interface or through any application that supports viewing of csv files.

### 3.2.2 Stimulus/Response Sequences

Data acquisition should begin as soon as the test sequence begins. Data will be viewable during the test and after the test concludes.

### 3.2.3 Functional Requirements

REQ ID	Requirement
SYS-8	The system shall record the chair's current position (steady state)
SYS-9	The system shall record the desired rpm set by the proctor
SYS-10	The system shall record the rpm that the chair is currently spinning at
SYS-11	The system shall record the time elapsed during the current test sequence
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
SYS-13	When the user indicates via the bi-directional control method, the system shall record the direction they think they are spinning in
SYS-14	When the user indicates via the bi-directional control method, the system shall record timestamps of when the button is triggered
SYS-15	The system shall have the ability to export data in a human-readable format
SYS-16	The system shall record acceleration data
SYS-17	The system shall record tachometer data
SYS-18	The system shall record all commands sent to the controller
SYS-19	The system shall record data at a sample rate of at least 20 HZ
SYS-68	The system shall record the time when the chair comes to a complete stop after the trial duration has elapsed
SYS-69	The system shall continue to record data until the proctor has signaled the end of the test



### 3.3 User Input/Feedback

#### 3.3.1 Description and Priority

The patient and proctor are both expected to interact with the system. In particular, the patient's input for what direction they are spinning in is a key deliverable of the system. The proctor is responsible for configuring, starting, and stopping the tests.

#### 3.3.2 Stimulus/Response Sequences

The proctor's input will begin as soon as the system has powered on and will last as long as the system is active. The user can begin interacting with the system as soon as the test sequence has begun.

#### 3.3.3 Functional Requirements

REQ ID	Requirement
SYS-20	The system shall support user input from a wireless bi-directional human input device
SYS-21	The system shall allow the user to indicate what direction they are spinning via a bi-directional control method
SYS-22	The system shall record intermediate values for the direction indicated
SYS-23	The system shall interface with a wireless bi-directional human input device such as a joystick or button
SYS-24	The proctor shall be able to press the "soft" kill switch (software) during operation to stop the chair in the event of an emergency
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)
SYS-26	The proctor shall be able to terminate power delivery to the chair by pressing a mechanical switch
SYS-27	The proctor shall set the duration of the test either via web interface or the controller module

### 3.4 Web Interface

#### 3.4.1 Description and Priority

The web interface is a requested feature to make it easier for the proctor to interact with the chair and collect data. While the web interface can be used to configure the test sequence, it does have greater priority than the control module.

#### 3.4.2 Stimulus/Response Sequences

The web interface shall allow proctor input as soon as a valid connection between the control module and the host PC has been established.

### 3.4.3 Functional Requirements

REQ ID	Requirement
SYS-28	The system shall support communication between an embedded target and a web interface via the UART protocol
SYS-29	The web interface shall support the exporting of data in a csv (or equivalent) file format
SYS-30	The web interface shall allow the operator to add different test sequences
SYS-31	The web interface shall display the system's status while the web interface is active, and a connection is established
SYS-32	The web interface shall not execute any commands unless the proctor has armed the system
SYS-33	The web interface shall not execute any commands unless connection with the control module has been established
SYS-34	The web interface shall not allow for user input unless connection with the control module has been established

## 3.5 Control Module Processing

### 3.5.1 Description and Priority

The controller module needs to be responsive to multiple changes in the system. Furthermore, it is responsible for accepting commands from either the physical I/O inputs or the web interface and processing them properly. Therefore, a robust and reliable processing environment is needed to ensure the system's operation is error free.

### 3.5.2 Stimulus/Response Sequences

The control module should begin accepting commands after all peripherals have been initialized. The control module will remain in this state while it remains powered.

### 3.5.3 Functional Requirements

REQ ID	Requirement
SYS-35	The controller module shall support the serial transmission of data to a receiver over a USB
SYS-36	The controller module shall support the UART/USART protocol to receive data from a host computer
SYS-37	The controller module shall be able to read analog values
SYS-38	The controller module shall have sufficient I/O (GPIO) to interface with a mechanical kill switch
SYS-39	The controller module shall support the I2C protocol for communicating with external peripherals
SYS-40	The controller shall utilize a potentiometer (or equivalent) to set desired RPM for the chair
SYS-41	The control shall utilize a potentiometer (or equivalent) to set desired test

	duration
SYS-42	Parameters set by the controller module shall not be overwritten by values set by the web interface if the test is currently executing
SYS-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
SYS-44	The controller shall utilize a state machine to control what operation is currently being executed.
SYS-45	<p>The system shall utilize a state machine with the following states:</p> <ol style="list-style-type: none"> <li>1. SYSTEM_INIT</li> <li>2. SEQUENCE_CONFIG</li> <li>3. ARM_HOLD</li> <li>4. ARMED</li> <li>5. ARMED_OPERATION</li> <li>6. TEST_COMPLETE</li> <li>7. EMERGENCY_STOP</li> </ol>

## 4. External Interface Requirements

Section 4 outlines the interface requirements for the system. This includes communication protocols and mediums utilized by the vestibular chair and aspects where user input is required.

### 4.1 Patient Input/Feedback

REQ ID	Requirement
SYS-46	The system shall support user input from a bi-directional input device
SYS-47	The system shall allow the user to indicate what direction they are spinning via a bi-directional control method
SYS-48	The system shall record intermediate values for the direction indicated
SYS-49	The control module shall interface with the bi-directional input device wirelessly

### 4.2 Proctor Input

REQ ID	Requirement
SYS-50	The proctor shall only be able to send commands to control module or start a test after a unique button/switch is pressed (arming switch)
SYS-51	The proctor shall be able to terminate power delivery to the chair by pressing a mechanical switch
SYS-52	The proctor shall be able to stop the currently executing test by pressing the "soft kill switch"

SYS-53	The proctor shall set the duration of the test either via web interface or through the potentiometers located on the controller module
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### 4.3 Web Interface

REQ ID	Requirement
SYS-54	The web interface shall allow the operator to add different test sequences
SYS-55	The web interface shall feature a unique button to select the test sequence
SYS-56	The web interface shall have a unique button to start the selected test sequence
SYS-57	The web interface shall have a text box to enter the duration of the test
SYS-58	The web interface shall display stored test sequences from a dropdown menu
SYS-71	The web interface shall display the current RPM of the chair

### 4.4 Hardware Communication Requirements

REQ ID	Requirement
SYS-59	The controller module shall support the serial transmission of data to a receiver over a USB
SYS-60	The controller module shall support the UART/USART protocol to receive data from a host computer
SYS-61	The controller module shall be able to read analog values
SYS-62	The controller module shall have sufficient I/O (GPIO) to interface with a mechanical kill switch
SYS-63	The controller module shall support the I2C protocol for communicating with external peripherals
SYS-64	The controller shall utilize a potentiometer (or equivalent) to set desired RPM for the chair
SYS-65	The controller shall support Bluetooth LE protocol for wireless communication
SYS-66	The controller shall run at a speed of at least 20MHz
SYS-67	The patient remote device shall support Bluetooth LE for wireless communication

## Other Nonfunctional Requirements

### 4.5 Hardware Requirements

REQ ID	Requirements
HDW-1	The motor shall spin no faster than 120 degrees per second
HDW-2	The motor shall constantly accelerate to 120 degrees per second
HDW-3	The motor shall not accelerate at 120 degrees per second until ordered to stop
HDW-4	The motor shall coast to a stop with constant deceleration
HDW-6	The chair shall be secured to the floor or structure as to prevent tipping and instability at 120 degrees per second
HDW-7	The chair shall have the controller affixed to the base when not in use
HDW-8	The power supply shall not exceed 12 amps output

HDW-9	The power supply shall not exceed 10 volts output
HDW-10	The power supply shall have a physical switch capable of disconnecting power
HDW-11	The physical switch shall not disconnect power to the control module
HDW-12	All wired connections between the top and base of the chair shall pass through the motor axle
HDW-13	All internal connections shall be made using soldered connections
HDW-14	System critical components such as power and I/O device lines shall utilize either solid core wire or a dedicate PCB solution.
HDW-15	The patient remote must have at least .25 inches of clearance for the physical buttons attached to the enclosure
HDW-16	The patient remote device must be battery powered during normal use
HDW-17	The system shall utilize a RJ45 port for power delivery to the chair
HDW-18	The system shall provide stress relief for all internal wires and connections

## 4.6 Performance Requirements

No requirements listed at this time.

## 4.7 Safety Requirements

SYS-4	The system shall not exceed 100 degrees per second (1 revolution every 3 seconds) at any point during its operation
SYS-6	If the chair reaches the target RPM, the system shall stop increasing the speed of the chair.
SYS-7	The chair shall not spin faster than the target RPM under any circumstance
SYS-24	The proctor shall be able to press the "soft" kill switch (software) during operation to stop the chair in the event of an emergency
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)
SYS-26	The proctor shall be able to terminate power delivery to the chair by pressing a mechanical switch
SYS-32	The web interface shall not execute any commands unless the proctor has armed the system
SYS-33	The web interface shall not execute any commands unless connection with the control module has been established
SYS-51	The proctor shall be able to terminate power delivery to the chair by pressing a mechanical switch
SYS-52	The proctor shall be able to stop the currently executing test by pressing the "soft kill switch"
HDW-1	The motor shall spin no faster than 120 degrees per second
HDW-6	The chair shall be secured to the floor or structure as to prevent tipping and instability at 120 degrees per second
HDW-9	The power supply shall not exceed 10 volts output
HDW-10	The power supply shall have a physical switch capable of disconnecting power

## 4.8 Security Requirements

No requirements listed at this time.

#### **4.9 Software Quality Attributes**

No requirements listed at this time.

#### **4.10 Business Rules**

No requirements listed at this time.

### **5. Other Requirements**

No requirements listed at this time.