System Requirements Specification

for

NASA Vestibular Chair

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Revision History

Name	Date	Reason For Changes	Version
Initial Draft (V1 Draft)	10/7/2022	Initial Release	0.1
V2 WIP	10/30/22	Update system requirements	0.11
V2	11/8/22	Version 2 release	0.2

1. Introduction

1.1 Purpose

This project is designed of restoring the NASA Vestibular Chair. The device was originally used in the late 1960s to conduct experiments and trials for astronauts and pilots to asses 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 involves restoring the basic functionality and then adding software functionality to improve the ease of use.

1.2 Document Conventions

- *Free coast*
- *RPM*

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.

Additional supporting documentation will be listed here at a later date.

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 is to analyze the current state of the chair, determine if it is still functional (pending modifications), 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 an embedded target. The commands are then processed by the embedded target and the vestibular chair will execute the desired command.

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*

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 the user believes they are spinning in throughout the test. This will be accomplished via a bi-directional input device such as a joystick 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 Operating Environment

2.4.1 Vestibular Chair:

The vestibular chair itself is the dynamic aspect of the system. This item mostly makes up the mechanical and electrical items of the project including an external power supply, a brushless motor for actuation, and multiple analog sensors. This aspect of the system has a hard limitation of 10v with the generated rpm being equivalent to the supplied voltage. The resulting output of the chair is determined based on the commands processed by the controller module.

2.4.2 Controller Module

The controller module consists of the software and hardware aspects of the project that will control the chair. We have selected an STM32 Nucleo-WB55RG development board to serve as our embedded computer. This choice was made due to its extensive library support, onboard peripherals including a Bluetooth module, performance compared to other microcontrollers, and availability. Additionally, the actuation of the motor is handled by a Pololu G2 24v12 motor controller. Other peripherals include two 4-digit seven-segment displays for debugging, potentiometers to control the desired rpm manually, and single pole single throw (SPST) switches for soft and hard suspension.

2.4.3 Web Interface

The web interface is the medium where the proctor can control the char for the patient. The purpose of this module is to give a front-end interface for the proctor to configure and execute test sequences. The corresponding commands are generated and then sent to the controller module via a serial protocol. Specific details regarding its implementation, requirements, and limitations are premature at this stage and will be included in later revisions.

2.5 Design and Implementation Constraints

2.5.1 Design Constraints

- The system cannot operate at greater than 10v. 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 down.

2.5.2 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 bidirectional input for the user is not feasible
- Desired RPM is also dependent on the patient's weight and posture in the chair

2.6 User Documentation

Nothing to list at this time

2.7 Assumptions and Dependencies

Nothing to list at this time

3. System Features

<This template illustrates organizing the functional requirements for the product by system features, the major services provided by the product. You may prefer to organize this section by use case, mode of operation, user class, object class, functional hierarchy, or combinations of these, whatever makes the most logical sense for your product.>

3.1 System Feature 1

<Don't really say "System Feature 1." State the feature name in just a few words.>

4.1.1 Description and Priority

<Provide a short description of the feature and indicate whether it is of High, Medium, or Low priority. You could also include specific priority component ratings, such as benefit, penalty, cost, and risk (each rated on a relative scale from a low of 1 to a high of 9).>

4.1.2 Stimulus/Response Sequences

<List the sequences of user actions and system responses that stimulate the behavior defined for this feature. These will correspond to the dialog elements associated with use cases.>

4.1.3 Functional Requirements

<Itemize the detailed functional requirements associated with this feature. These are the software capabilities that must be present in order for the user to carry out the services provided by the feature, or to execute the use case. Include how the product should respond to anticipated error conditions or invalid inputs. Requirements should be concise, complete, unambiguous, verifiable, and necessary. Use "TBD" as a placeholder to indicate when necessary information is not yet available.>

<Each requirement should be uniquely identified with a sequence number or a meaningful tag of some kind.>

REQ-1:
REQ-2:

3.2 System Feature 2 (and so on)

4. External Interface Requirements

Section 4 covers information regarding the usage and core functionality of the system. Sections 4.1 outlines the motor control requirements. Section 4.2 states the requirements for data acquisition. 4.3 outlines user input and feedback. Sections 4.4 and 4.5 outline the web interface and controller requirements respectfully.

4.1 Chair/Motor Control

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 should enter a free coast state
SYS-3	The system should allow the chair to spin in either clockwise or counterclockwise directions
SYS-4	The system shall have two "soft" kill switches that will allow the chair to "free coast" down to 0 rpm
SYS-4.1	One of the "soft" kill switches shall be located on the chair in a position that is accessible by the user
SYS-4.2	One of the “soft” kill switches shall be located on the proctor’s controller interface
SYS-5	The system shall have a "hard" mechanical kill switch that will disable power delivery to the chair
SYS-6	The system shall have a mechanical switch that will enable power delivery to the chair
SYS-7	The system should adjust the voltage to the motors in response to the user's weight to maintain the desired rate/RPM
SYS-8	The system shall not exceed 100 degrees per second (1 revolution every 3 seconds) at any point during its operation

4.2 Data Acquisition

REQ ID	Requirement
SYS-9	The system shall record the chair's current position (steady state)
SYS-10	The system shall record the desired rpm set by the proctor
SYS-11	The system shall record the rpm that the chair is currently spinning at
SYS-12	The system shall record the time elapsed during the current test sequence
SYS-13	When the user indicates via the bi-directional control method, the system shall record the total time the user indicates they are spinning
SYS-14	When the user indicates via the bi-directional control method, the system shall record the direction they think they are spinning in
SYS-15	When the user indicates via the bi-directional control method, the system shall record timestamps of when the button is triggered
SYS-16	The system shall have the ability to export data in a human-readable format
SYS-17	The system shall record acceleration data
SYS-18	The system shall record tachometer data
SYS-19	The system shall record the current direction of the chair
SYS-20	The system shall record all commands sent to the controller

4.3 User Input/Feedback

REQ ID	Requirement
SYS-21	The system shall support user input from a bi-directional control interface
SYS-22	The system shall allow the user to indicate what direction they are spinning via a bi-directional control method
SYS-23	The system shall record intermediate values for the direction indicated
SYS-24	The system must interface with a wireless bi-directional controller such as a joystick or button
SYS-25	The user shall be able to press the "soft" kill switch during operation to stop the chair in the event of an emergency

4.4 Proctor Requirements

REQ ID	Requirement
SYS-26	The proctor shall only be able to actuate the chair or start a test after a unique button/switch is pressed (arming switch)

4.5 Web Interface

REQ ID	Requirement
SYS-28	The web interface shall allow the operator to add different test sequences
SYS-29	The web interface shall allow the proctor to input the user's weight
SYS-30	The web interface shall feature a unique button to select the test sequence
SYS-31	The web interface shall have a unique button to start the selected test sequence
SYS-32	The web interface shall have a text box to enter the duration of the test
SYS-33	The web interface shall display stored test sequences from a dropdown menu

NOTE: The web interface is not the current focus of development so an initial set of general requirements are provided. This list will be expanded upon as development continues.

4.6 Controller Requirements

REQ ID	Requirement
SYS-34	The controller module shall support the serial transmission of data to a receiver over a USB
SYS-35	The controller module shall support the UART/USART protocol to receive data from a host computer
SYS-36	The controller module shall be able to read analog values
SYS-37	The controller module shall have sufficient I/O (GPIO) to interface with a mechanical kill switch
SYS-38	The controller module shall support the I2C protocol for communicating with external peripherals
SYS-39	The controller shall utilize a potentiometer (or equivalent) to set desired RPM for the chair
SYS-40	The controller module shall utilize two 4-digit seven segment displays for debugging and displaying immediate data

4.7 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-5	The motor shall be able to spin in either clockwise or counterclockwise directions
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 must not exceed 12 amps output
HDW-9	The power supply must not exceed 10 volts output
HDW-10	The power supply shall have a physical switch capable of disconnecting power
HDW-11	All wired connections between the top and base of the chair must pass through the motor axle

Other Nonfunctional Requirements

4.8 Performance Requirements

<If there are performance requirements for the product under various circumstances, state them here and explain their rationale, to help the developers understand the intent and make suitable design choices. Specify the timing relationships for real time systems. Make such requirements as specific as possible. You may need to state performance requirements for individual functional requirements or features.>

4.9 Safety Requirements

<Specify those requirements that are concerned with possible loss, damage, or harm that could result from the use of the product. Define any safeguards or actions that must be taken, as well as actions that must be prevented. Refer to any external policies or regulations that state safety issues that affect the product's design or use. Define any safety certifications that must be satisfied.>

4.10 Security Requirements

<Specify any requirements regarding security or privacy issues surrounding use of the product or protection of the data used or created by the product. Define any user identity authentication requirements. Refer to any external policies or regulations containing security issues that affect the product. Define any security or privacy certifications that must be satisfied.>

4.11 Software Quality Attributes

<Specify any additional quality characteristics for the product that will be important to either the customers or the developers. Some to consider are: adaptability, availability, correctness, flexibility, interoperability, maintainability, portability, reliability, reusability, robustness, testability, and

usability. Write these to be specific, quantitative, and verifiable when possible. At the least, clarify the relative preferences for various attributes, such as ease of use over ease of learning.>

4.12 Business Rules

<List any operating principles about the product, such as which individuals or roles can perform which functions under specific circumstances. These are not functional requirements in themselves, but they may imply certain functional requirements to enforce the rules.>

5. Other Requirements

<Define any other requirements not covered elsewhere in the SRS. This might include database requirements, internationalization requirements, legal requirements, reuse objectives for the project, and so on. Add any new sections that are pertinent to the project.>

Appendix A: Glossary

<Define all the terms necessary to properly interpret the SRS, including acronyms and abbreviations. You may wish to build a separate glossary that spans multiple projects or the entire organization, and just include terms specific to a single project in each SRS.>

Appendix B: Analysis Models

<Optionally, include any pertinent analysis models, such as data flow diagrams, class diagrams, state-transition diagrams, or entity-relationship diagrams.>

Appendix C: To Be Determined List

<Collect a numbered list of the TBD (to be determined) references that remain in the SRS so they can be tracked to closure.>