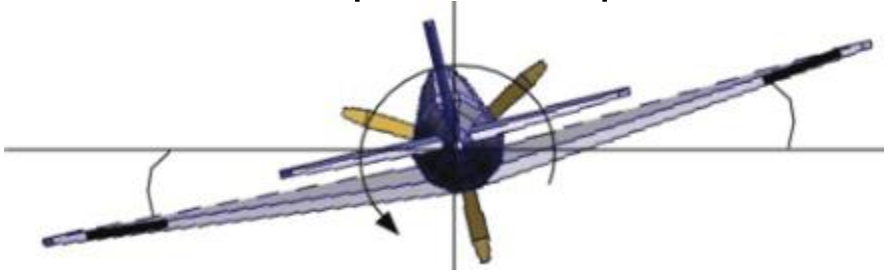
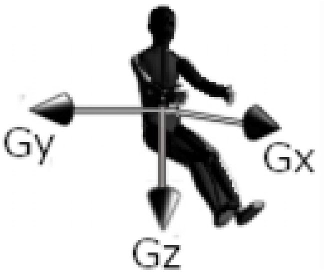
Test Readiness Review

CHAIR
March 3, 2021

CHAIR Overview

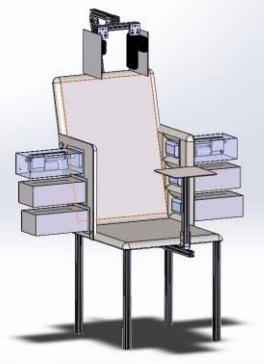
- **Customer's Goal**
  - Provide multiple sensory cues to remote pilots to increase aircraft attitude awareness
- **Team CHAIR's Role**
  - Create a proof of concept research tool that can be further developed into a complete system used by remote pilots
- **Levels of Success**
  - Level 1: Discrete, static tilt cueing about the body x axis
  - Level 2: Continuous, sinusoidal tilt cueing about the body x axis
  - Level 3: Variable tilt profile developed in real time through joystick control



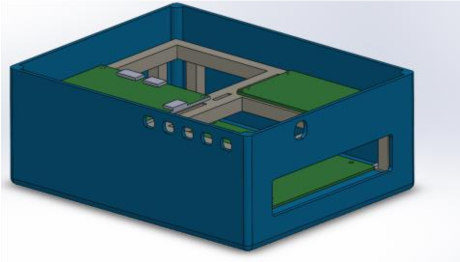


Critical Project Elements

- **TCS** (Tactile Cueing System)
  - 3 pressure plates on each side
  - Actuators, Circuits and Hardware
  - Extension of pressure pads integrated with sensor feedback



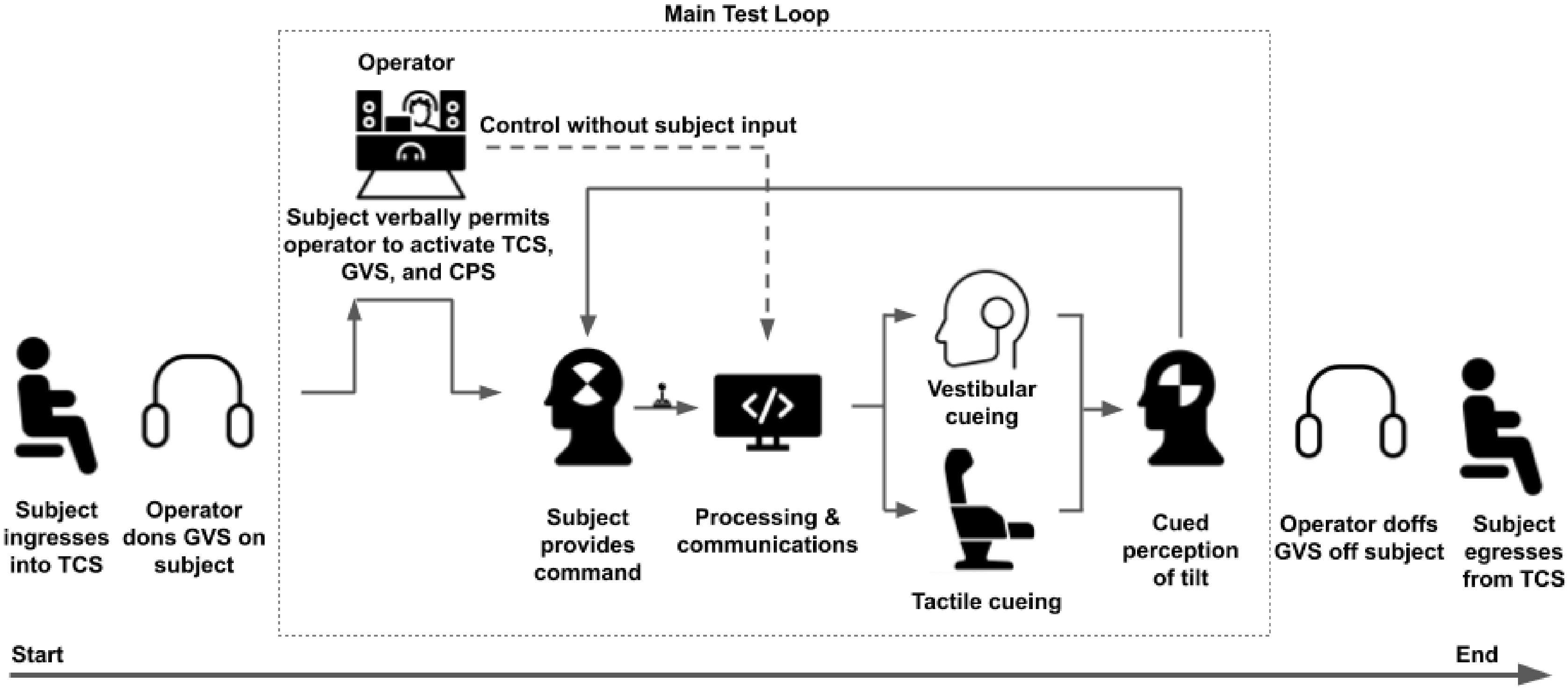
- **GVS** (Galvanic Vestibular Stimulator)
  - Multi-Electrode Setup
  - Skin-Electrode Interface
  - Current Control



- **CPS** (Central Processing System)
  - Control Flow
  - Interfacing with the TCS, GVS or GUI

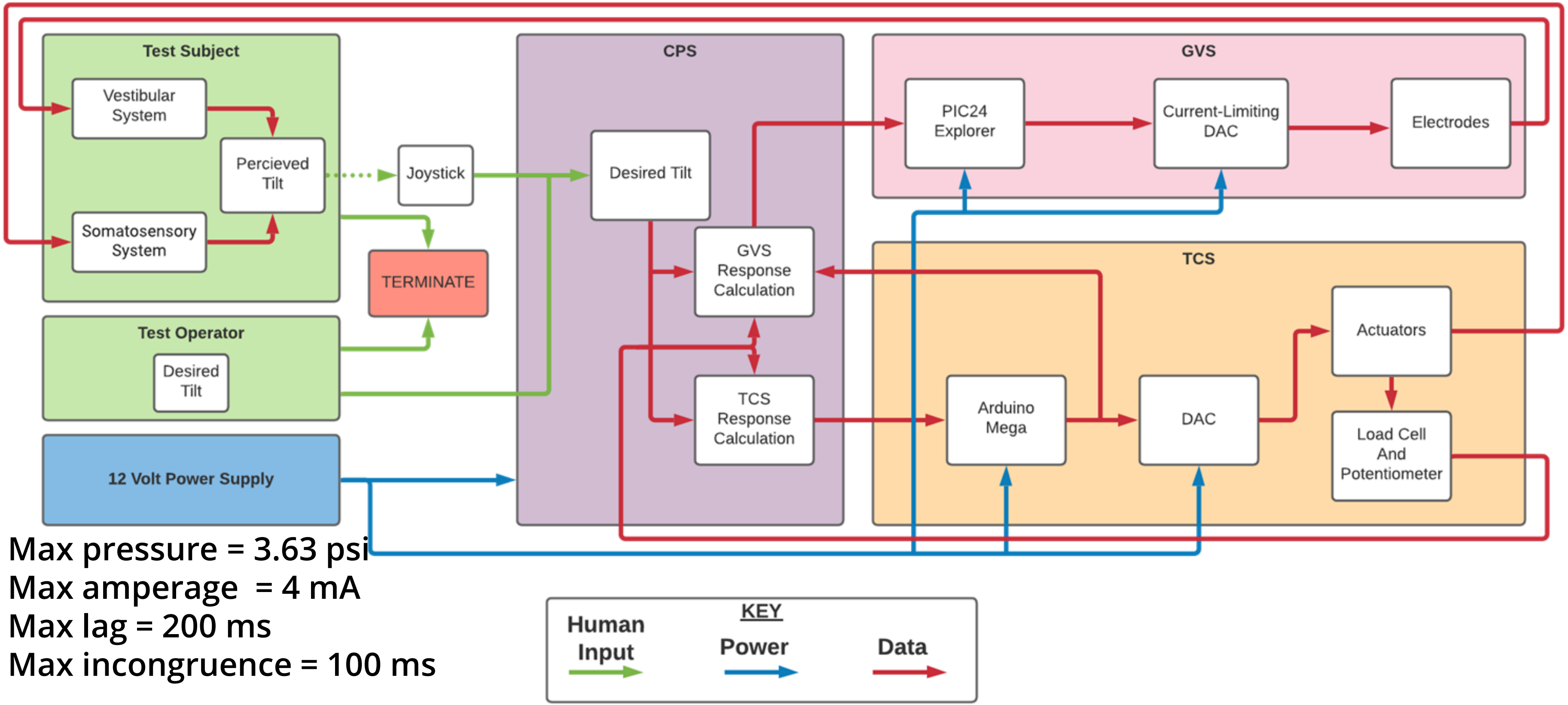
```
// TCS_Comm_App.cpp : This file contains the source code for tansmitting and recieving data with the TCS.
//

#include <iostream>
#include "SerialClass.h"



Serial::Serial(const char* COM3)
{
    //We're not yet connected
    this->connected = false;

    //Try to connect to the given port throuh CreateFile
    this->hSerial = CreateFileA(COM3,
        GENERIC_READ | GENERIC_WRITE,
        0,
        NULL,
        OPEN_EXISTING,
        FILE_ATTRIBUTE_NORMAL,
        NULL);

    //Check if the connection was successfull
    if (this->hSerial == INVALID_HANDLE_VALUE)
    {
        //If not success full display an Error
        if (GetLastError() == ERROR_FILE_NOT_FOUND) {

            //Print Error if neccessary
            printf("ERROR: Handle was not attached. Reason: %s not available.\n", COM3);

        }
        else
        {
            printf("ERROR!!!");
        }
    }
    else
    {
        //If connected we try to set the comm parameters
        DCB dcbSerialParams = { 0 };

        //Try to get the current
        if (!GetCommState(this->hSerial, &dcbSerialParams))
        {
            //If impossible, show an error
            printf("failed to get current serial parameters!");
        }
        else
        {
            //Define serial connection parameters: Baud, Bytes, Parity
            dcbSerialParams.BaudRate = CBR_115200;
            dcbSerialParams.ByteSize = 8;
            dcbSerialParams.StopBits = ONESTOPBIT;
            dcbSerialParams.Parity = NOPARITY;
```

ConOps



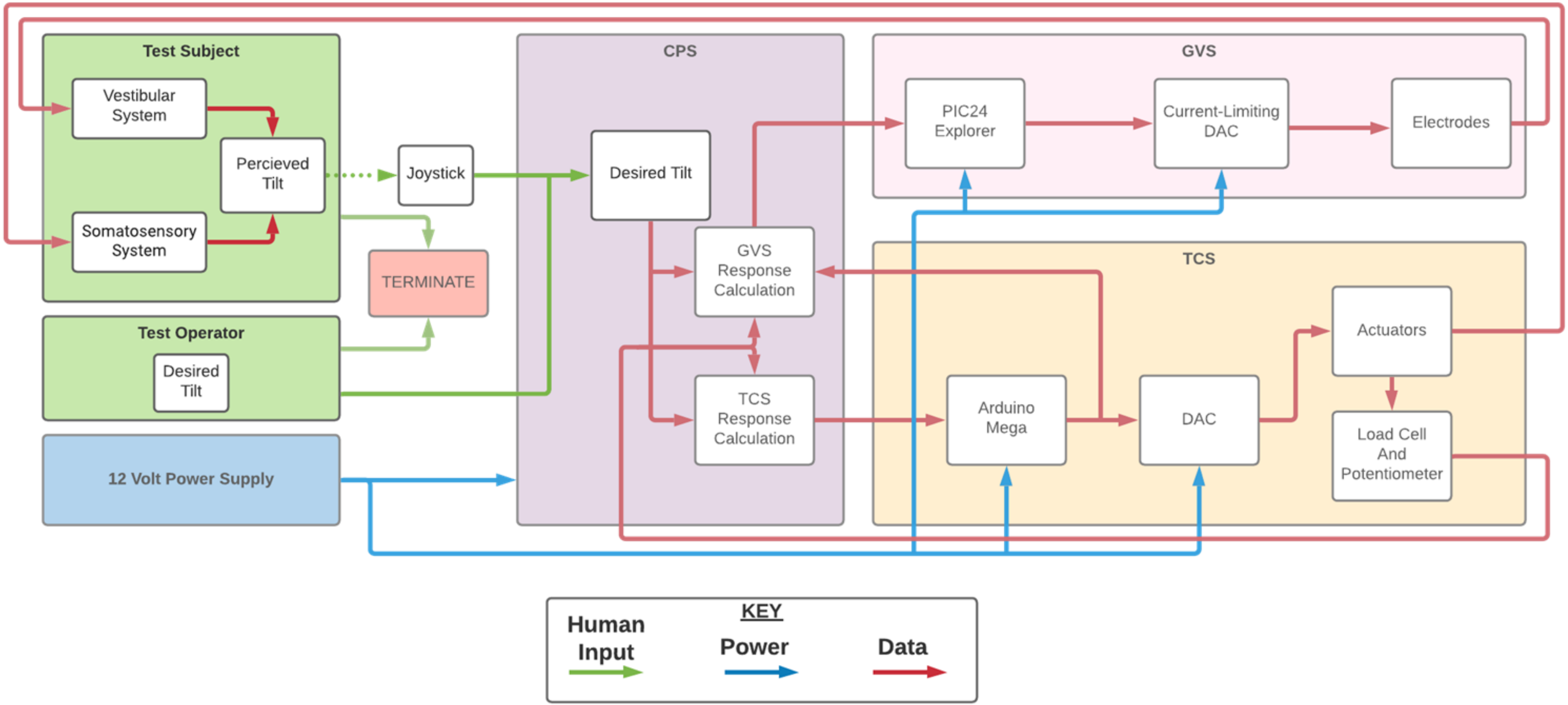
Main Test Loop
Operator
Control without subject input
Subject verbally permits operator to activate TCS, GVS, and CPS
Subject ingresses into TCS
Operator dons GVS on subject
Subject provides command
Processing & communications
Vestibular cueing
Tactile cueing
Cued perception of tilt
Operator doffs GVS off subject
Subject egresses from TCS
Start
End

Functional Block Diagram

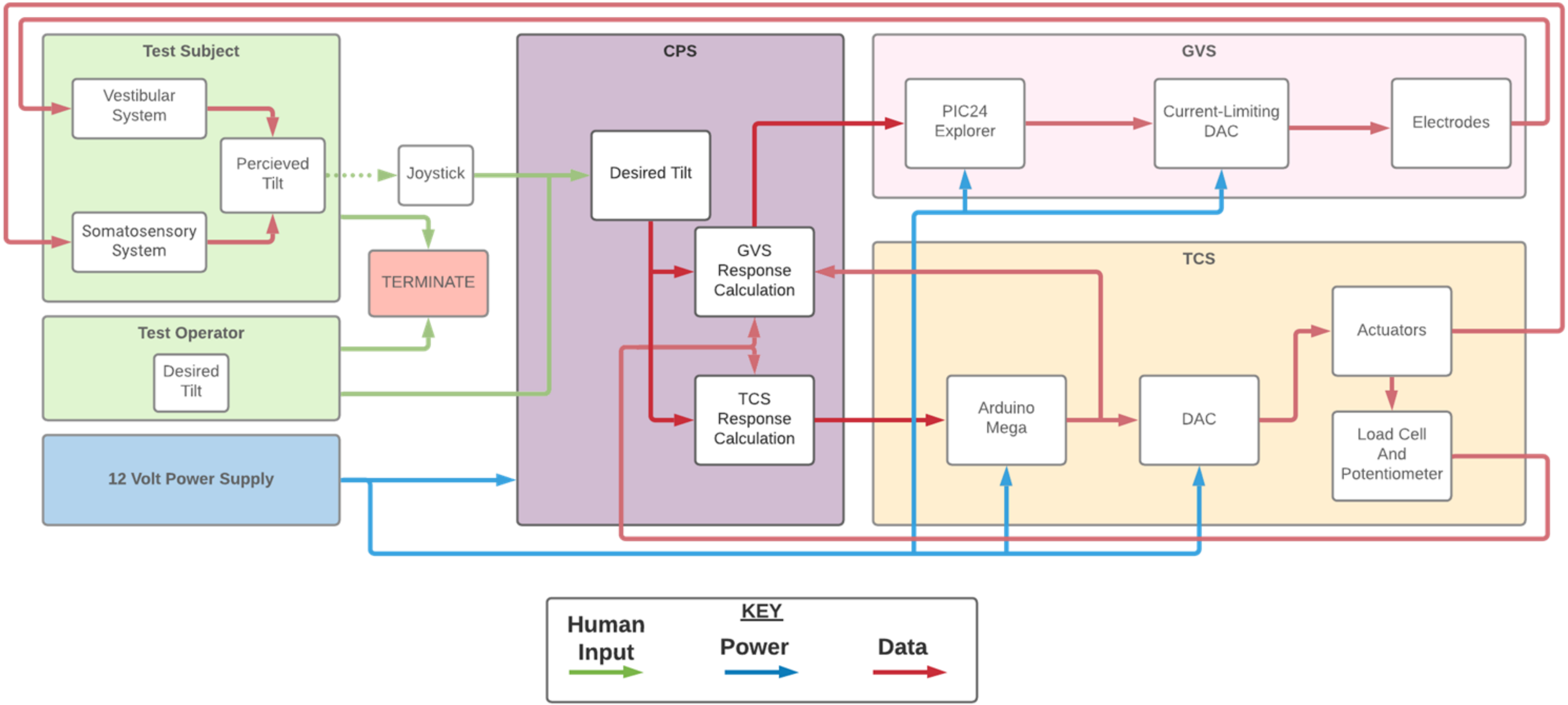


Max pressure = 3.63 psi
Max amperage = 4 mA
Max lag = 200 ms
Max incongruence = 100 ms

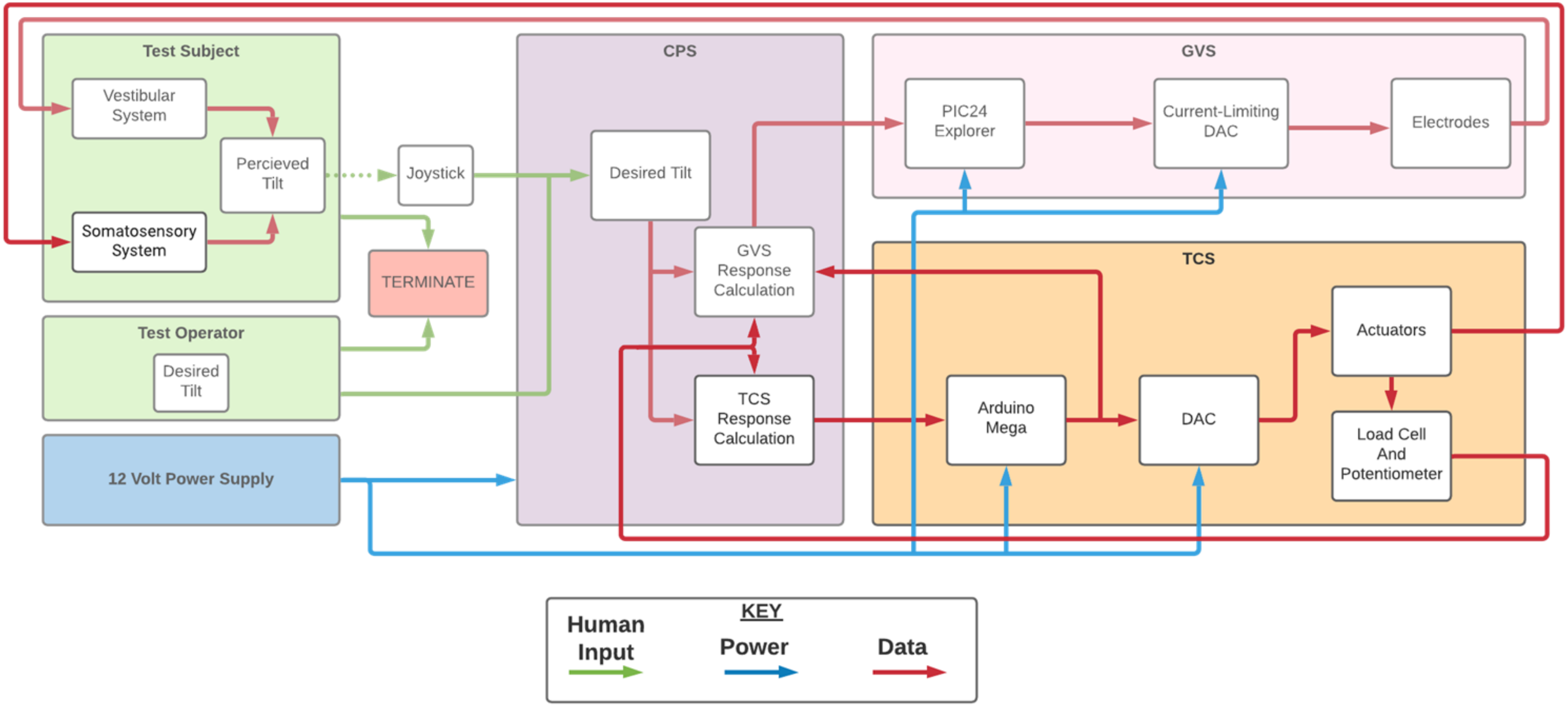
Functional Block Diagram



Functional Block Diagram



Functional Block Diagram



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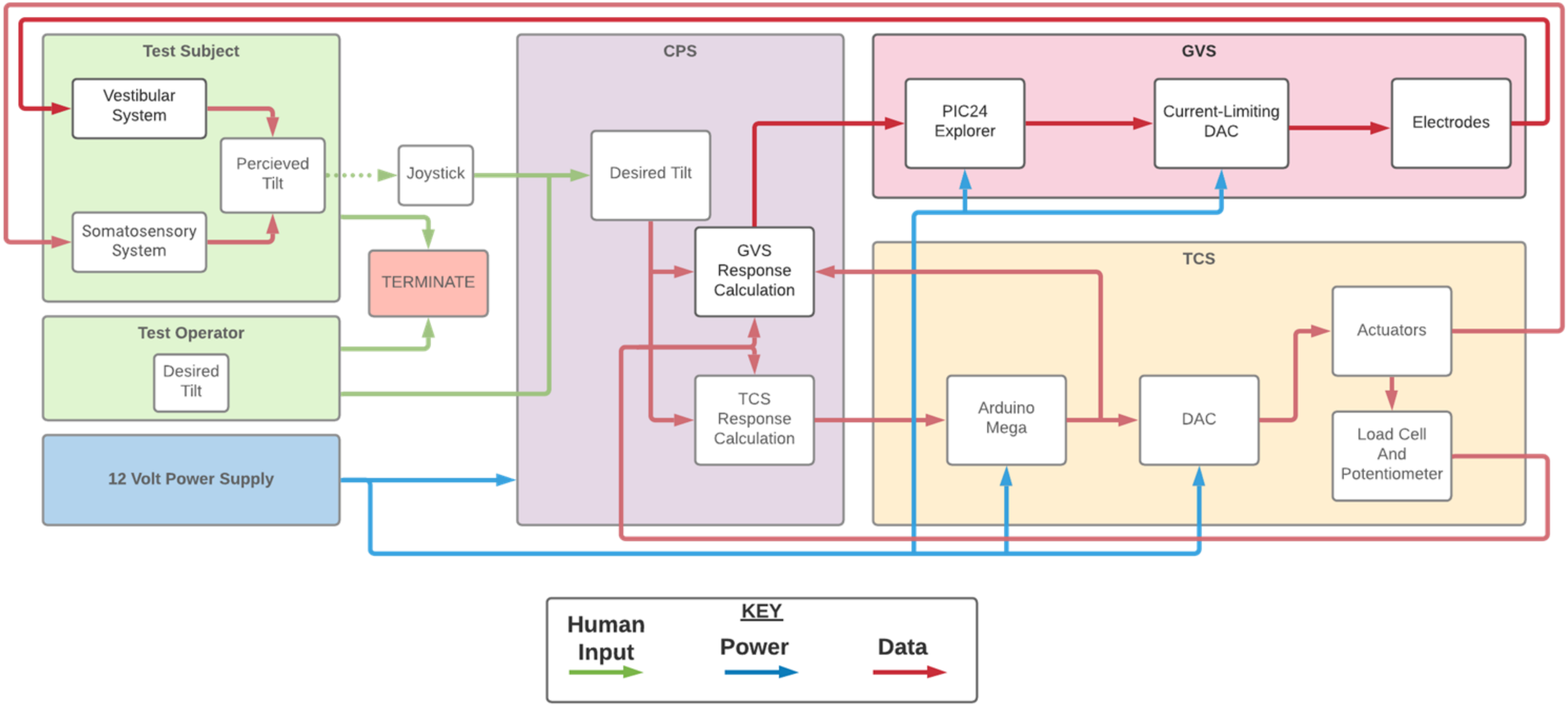

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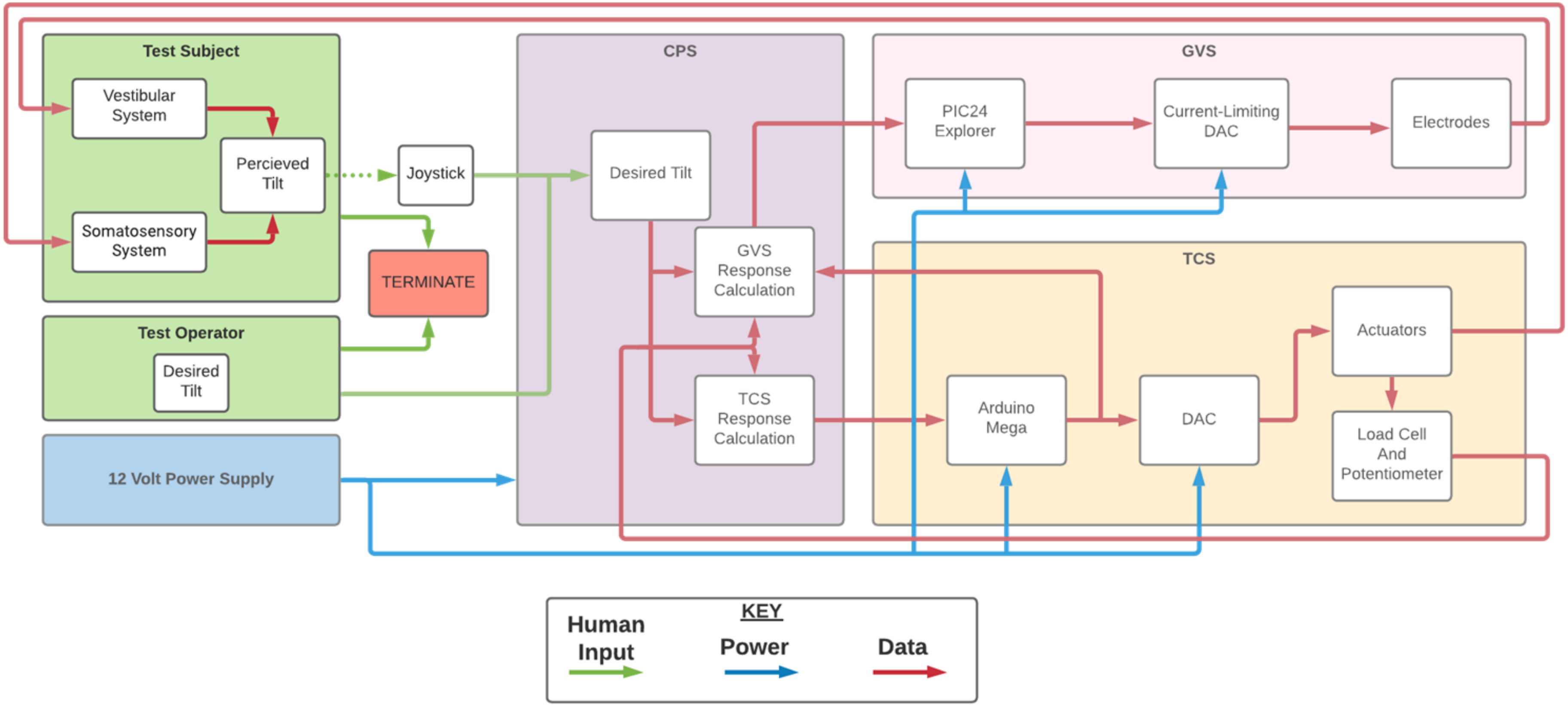
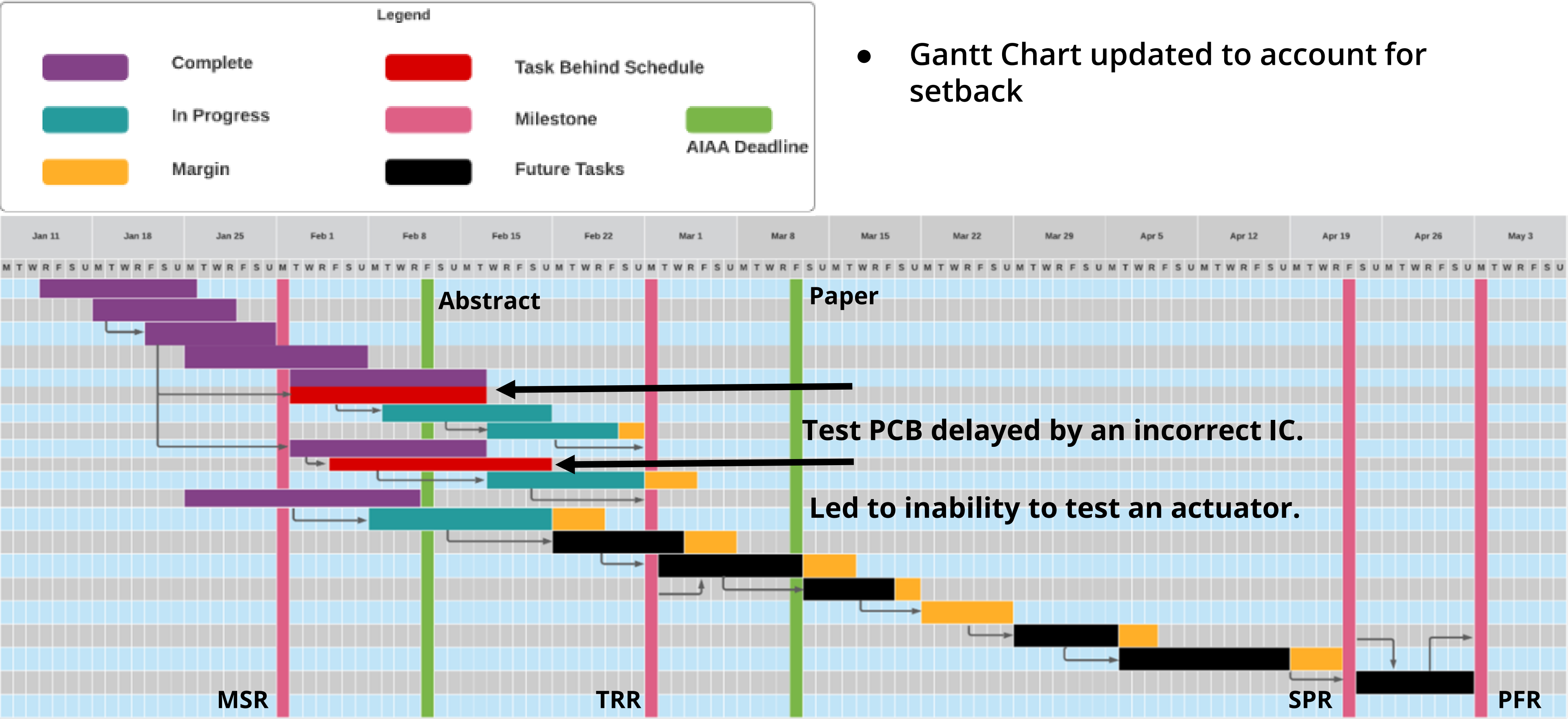
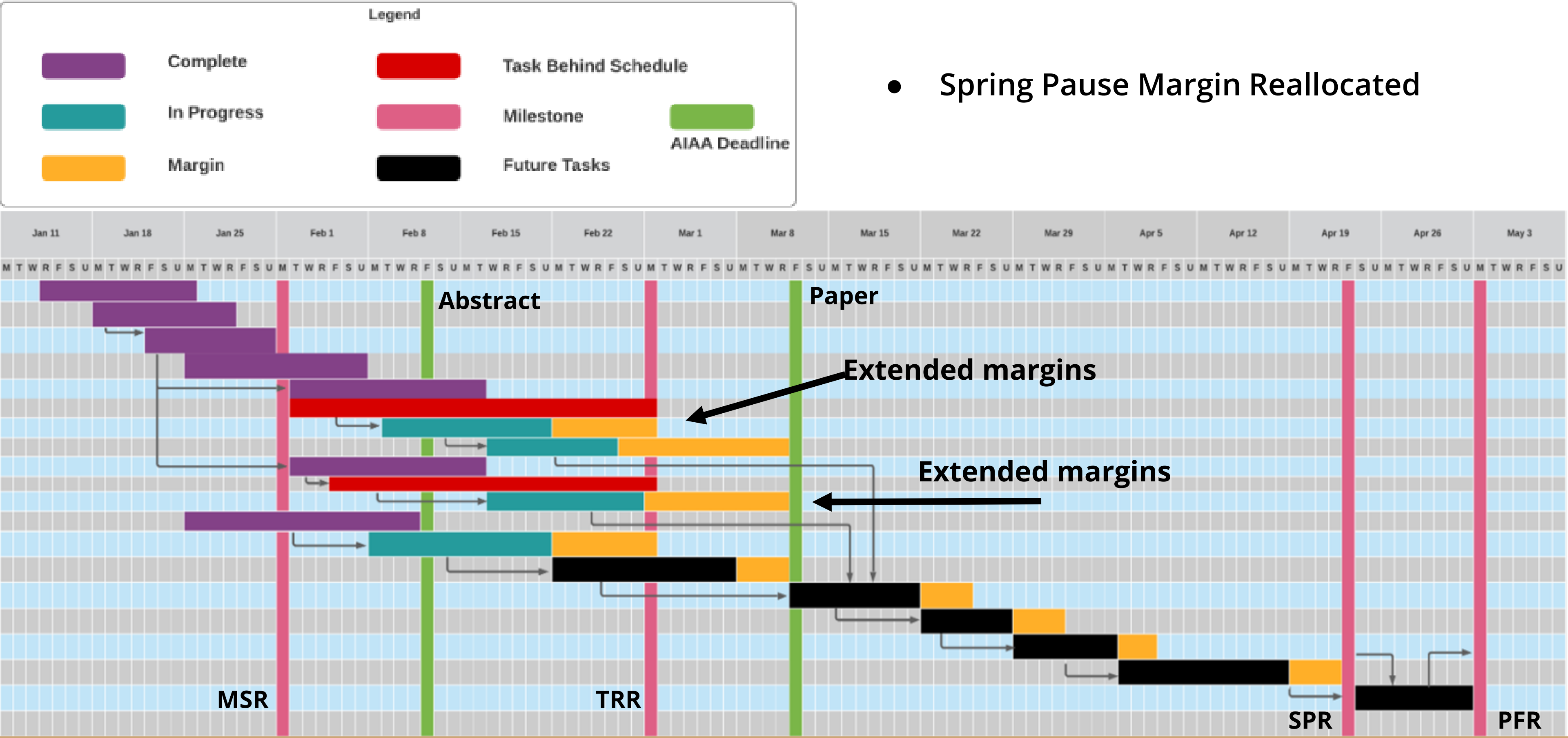


Schedule



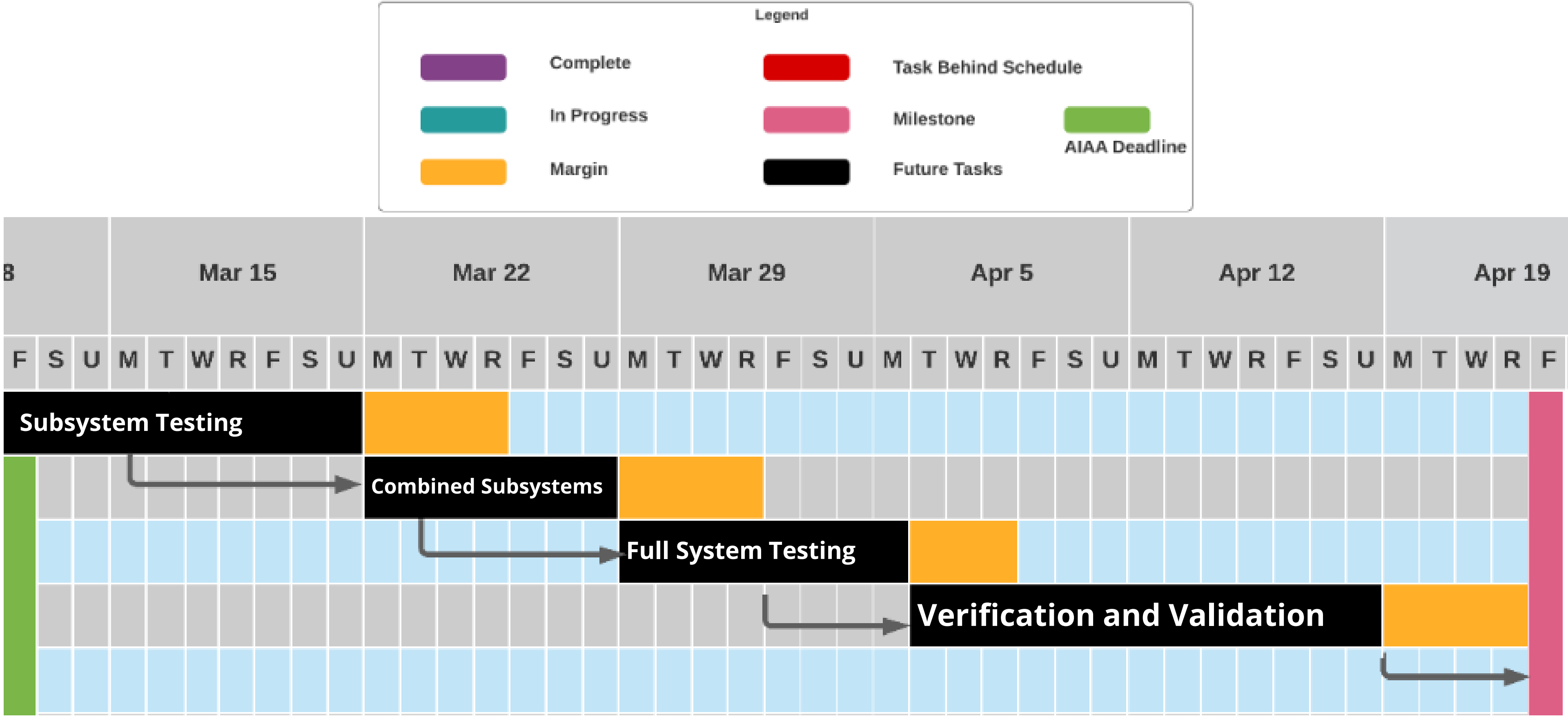
- Gantt Chart updated to account for setback

Updated Schedule

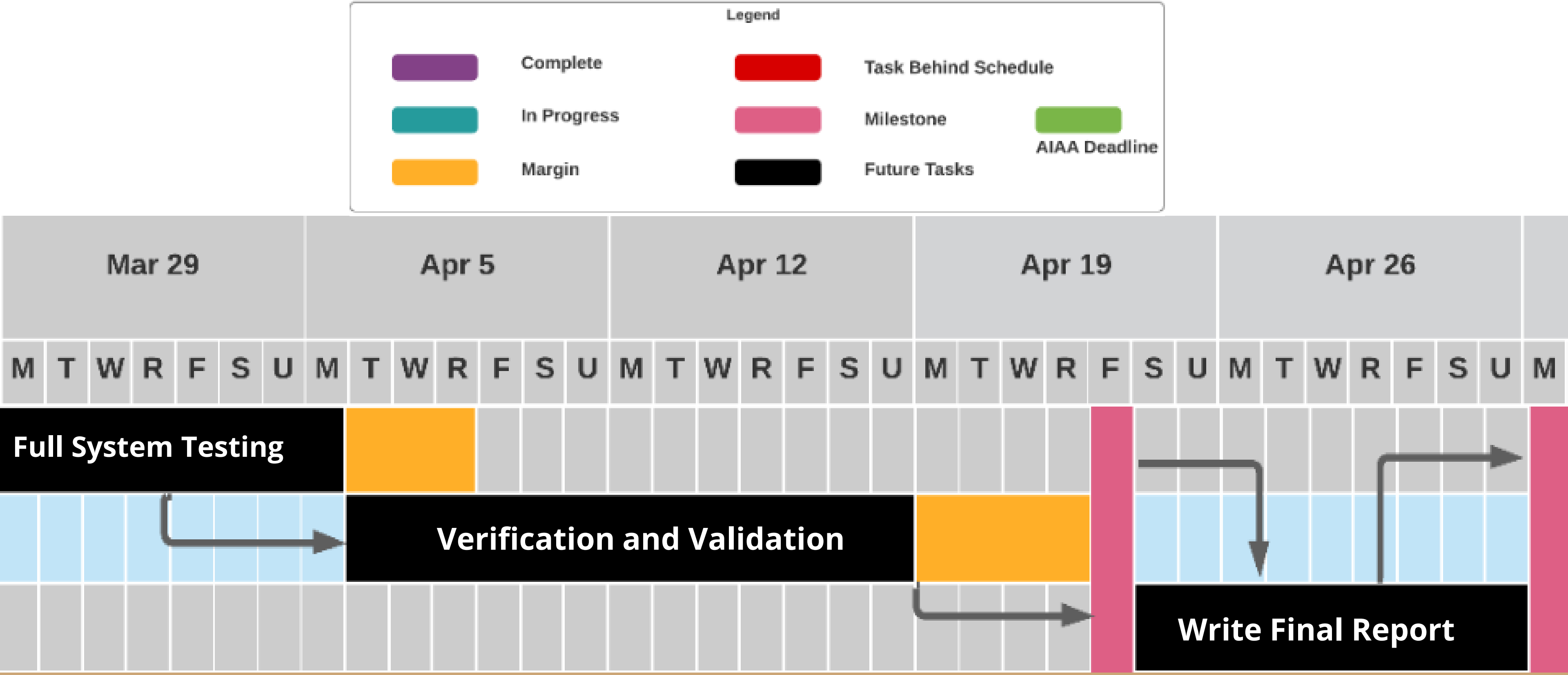


- Spring Pause Margin Reallocated

Updated Schedule

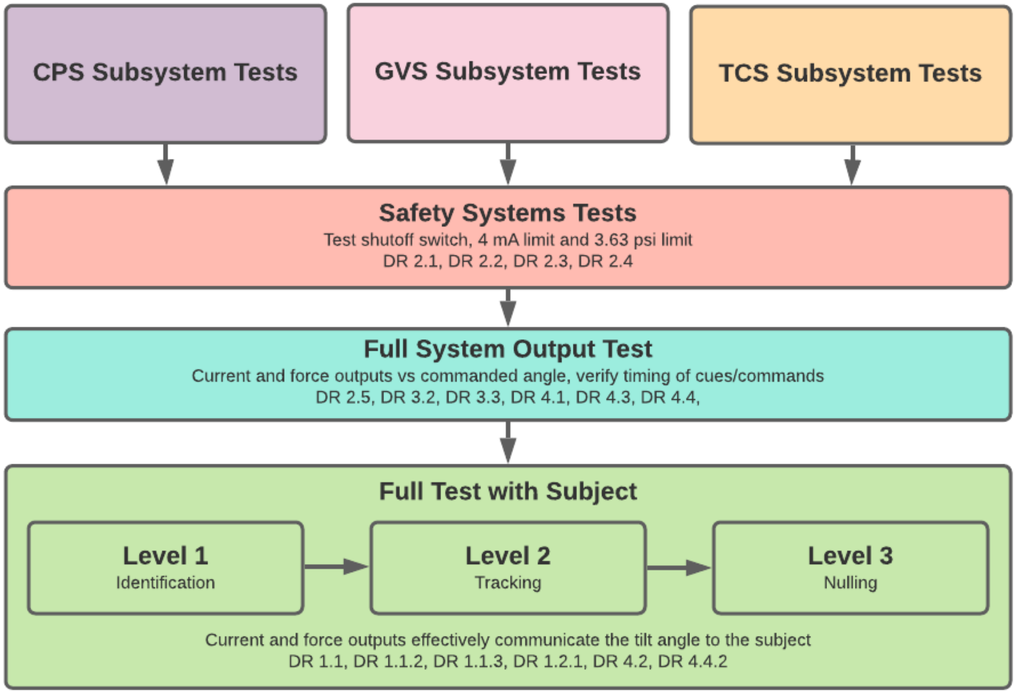


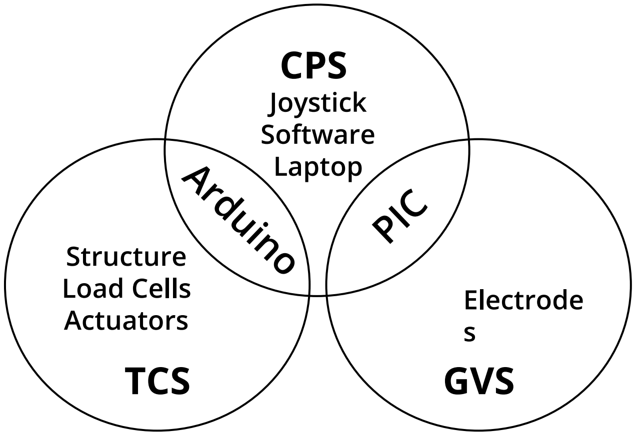
Updated Schedule



Test Readiness

Testing Plan Overview





CPS Complete Test List

Planned
In progress
Complete
⚠ Safety

Test Name	Description	Driving Requirements	Status
CPS Safety Test	/		
⚠ Test Subject Button	Verify functionality of the test subject's terminate button	DR 2.5	IN PROGRESS
⚠ Operator Button	Verify functionality of the operator's terminate button	DR 2.5	COMPLETE
⚠ Joystick Interference	Command a safe value but make it unsafe with joystick augmentation and ensure that it still terminates.	DR 2.4,	PLANNED
⚠ TCS Safe Level	Record feedback data from the Arduino (load cells) to verify force of actuation. Ensure it is within safe bounds.	DR 2.4	PLANNED
⚠ TCS Malicious Feedback	Create unsafe feedback from the TCS load cells and ensure that the test terminates	DR 2.4	PLANNED
⚠ CPS Command	Record the CPS output while having operator command values higher than the allowed maximums. Ensure CPS does not command the in-appropriate values.	DR 2.4	COMPLETE
Supporting Tests	/		
CPS File Read	Verify that the CPS can successfully read files in the correct format		COMPLETE
CPS Data Processing	Check that the given data is processed into the desired format		COMPLETE
CPS Joystick Mode	Check that different joystick modes lead to the appropriate programs being run		COMPLETE
CPS to GVS Comms	Establish UART Communication for the PIC and verify data sent & received.	DR 3.2,DR 3.3,DR 3.4	PLANNED
CPS to TCS Comms	Establish UART Communication for the Arduino and verify data sent & received.	DR 3.1,DR 3.2,DR 3.3,DR 3.4	PLANNED
CPS to TCS Command	Integrate Arduino software with the test hardware to fully test and tune a single actuator.	DR 3.1,DR 3.2,DR 3.3,DR 3.4	PLANNED
CPS to GVS Command	Integrate PIC software with the test hardware to fully test and tune GVS.	DR 3.2,DR 3.3,DR 3.4	PLANNED
System Comms	Verify successful communication & integration of both subsystems with CPS main program.	DR 3.1,DR 3.2,DR 3.3,DR 3.4	PLANNED
Joystick Comms	Verify that the CPS can read the joystick data	DR 2.4 ,DR 2.5,DR 3.3	IN PROGRESS
Terminate Response Time	Record CPS output and measure time between stop switch and outputs reaching 0	DR 2.5	PLANNED
Joystick Delay	Record joystick input and CPS output and measure delay between command and cue (will need to be less than 200 ms to allow for actuation)	DR 3.3	PLANNED
Sync	Use the user interface to command GVS and TCS magnitude and direction. Measure the microcontroller outputs to make sure they match up.	DR 3.4	PLANNED
Sync Delay	Record signal sent to TCS and signal sent to GVS and measure delay between equal states (will need to be less than 100 ms to allow for actuation)	DR 3.2	PLANNED

TCS Complete Test List

Legend
Planned
In progress
Complete
⚠ Safety

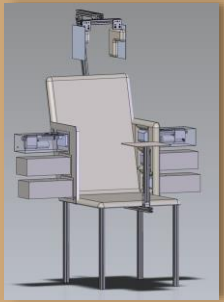
Test Name	Description	Driving Requirements	Status
Electrical component verification test	Verify that individually all components behave as described by the manufacturer	DR 1.1,DR 1.1.1 ,DR 1.1.3,DR 2.1,DR 2.2	IN PROGRESS
Single Command Single Actuator PCB test	Verify that the single actuator PCB is capable of commanding an uncontrolled force through the actuator	DR 1.1,DR 1.1.1,DR 1.1.3,DR 2.1	PLANNED
Single Actuator Controls Test	Implement designed controls logic to command a range of forces dictated by tester on a single actuator	DR 1.1,DR 1.1.1 ,DR 1.1.3,DR 2.1	PLANNED
Actuator Assembly Test	Implement commands to an actuator once assembled in the housing and attached to the chair	DR 1.1, DR 1.1.1 ,DR 2.1	PLANNED
Single actuator over commanding test	Verify system actuator does not output more than 25 kPa when commanded above the required maximum	DR 1.1,DR 1.1.1 ,DR 1.1.3,DR 2.1	PLANNED
⚠ Actuator Performance Test	Verify actuator performance is within pressure bounds when assembled and attached to the chair	DR 1.1,DR 1.1.3,DR 2.1	PLANNED
Lab space test	Verify that the structure can fit within 6'x6' lab space	DR 4.1,DR 4.2	COMPLETE
⚠ Seat Pan structural test	Verify that the seat pan can support the customer's weight. with a FOS of 1.2	DR 1.1.2,DR 4.2	PLANNED
⚠ Seat back structural test	Verify that the seat back can support the back forces imparted by the customer with a FOS of 1.2	DR 1.1.2,DR 4.2	PLANNED
⚠ Center of Gravity Test	Testing the center of gravity is over the seat pan when in operation	DR 1.1.2,DR 4.2	PLANNED
Verify correct dimensions test	At least a 0.5" clearance between all surfaces except for the seat back, seat pan, and headrest.	DR 4.1,DR 4.2	IN PROGRESS
Actuator Extension Test	Validate appropriate extension.	DR 1.1,DR 1.1.3	PLANNED
Structural endurance test	Verify structural integrity after prolonged operation.	DR 4.2,DR 4.4,DR 4.4.2	PLANNED
Multiple Operations Test	Operation system over multiple full cycle operations	DR 4.3,DR 4.4,DR 4.4.2	PLANNED

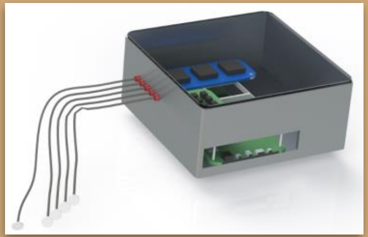
GVS Complete Test List

Legend
Planned
In progress
Complete
⚠ Safety

Test Name	Description	Driving Requirements	Status
Float conversion via UART test	Send a UART command, set a debug breakpoint after the float conversion, verify successful interpretation	DR 1.2	COMPLETE
SPI Output test	Set a constant SPI output. Execute this command. Analyze endianness, speed, CS behavior	DR 1.2	COMPLETE
PCB Connection Test	Use a multimeter in buzzer mode to test all connections between the pins on the custom PCB	DR 1.2	COMPLETE
⚠ Send a +000 and -000	Verify no operation	DR 1.2	PLANNED
⚠ Send +400, +000, -400, +000 in order	DR 1.2.1, also verifies current can be stopped with cmd Assess signal stability over time. (what is stable?)	DR 1.2,DR 2.3	PLANNED
Send various values between [+400 and -400]	(valid codes, should be accepted and written)	DR 1.2,DR 2.3	PLANNED
Send values between [+625 +400] and [-625 and -400]	(valid DAC codes exist, but should be rejected by the uC)	DR 1.2,DR 2.3	PLANNED
Send values in excess of +625 and -625	(valid DAC codes do not exist, should be rejected by uC)	DR 1.2,DR 2.3	PLANNED
⚠ Send junk values	(e.g., 9999, asdf, ~$@#$, all should be rejected) Might need to add num-specific acceptance criteria	DR 2.3	PLANNED
⚠ Middle glitch power test	Test and measure middle glitch power, i.e. the maximum error on value transition. Send +3.12, then send +3.13, then repeat for the negatives		PLANNED
⚠ Start a 1mA current, leave running for 20 minutes,	verify current accuracy is acceptable (what is acceptable?). Repeat for 4mA	DR 4.4.2,DR 4.4	PLANNED
POR test	Press the Power button. Record current. Press again. Record current.	DR 4.4.2,DR 4.4	PLANNED
Unplug UART/Power test	Send 4mA current cmd, unplug device. Record current. Plug back in. Record current.		PLANNED
Unplug 24V power test	Send 4mA current cmd, unplug 24V power. Record current. Plug bag in. Record current.	DR 4.4.2,DR 4.4	PLANNED
Apply electrodes across the mastoids. Send a +/- 1mA command	Assess current response	DR 1.2	PLANNED
Send a +/- 4mA command.	Assess current response.	DR 1.2	PLANNED
5-Electrode Testing Mode	Repeat all relevant tests for 5 electrodes	Reach Goal	PLANNED

Subsystem Test Overview





CPS	
CPS Command	Complete
CPS to GVS Comms	Planned
CPS to GVS Command	Planned
Sync Delay	Planned
Test Subject Button	In progress

TCS	
Seat Structural	Planned
Center of Gravity	Planned
Actuator Assembly	Planned
Actuator Performance	Planned

GVS	
Software & Component	In Progress
Resistor “dummy load”	Planned
Human testing	Planned

Central Processing System Testing

CPS	
CPS Command	**Complete**
CPS to GVS Comms	Planned
CPS to GVS Command	Planned
Sync Delay	Planned
Test Subject Button	In progress

Equipment: Laptop
Expected Results: Safe and correct value will be calculated/logged. Unsafe commands will be captured, changed and alerted to operator

Rationale: CPS needs to command correct and safe state values. Motivated by DR 2.4

Procedure: Send commands via operator command-line and joystick. Verify correctness. Verify unsafe commands are captured,changed and alerted.

Risk Reduction: To ensure the safety of the system it is vital that the CPS calculate the correct state and limit unsafe inputs.

Central Processing System Testing

CPS	
CPS Command	Complete
CPS to GVS Comms	**Planned**
CPS to GVS Command	Planned
Sync Delay	Planned
Test Subject Button	In progress

Equipment: Laptop, USB cable, and GVS PIC
Expected Results: Communication will work

Rationale: Ensure communication between CPS and GVS. Motivated by DR 3.2, DR 3.3 and DR 3.4

Procedure: Command CPS to send a signal and check that the correct value is received by the GVS.

Risk Reduction: Secure and positive communication with the GVS is instrumental to safe operation.

Central Processing System Testing

CPS	
CPS Command	Complete
CPS to GVS Comms	Planned
CPS to GVS Command	**Planned**
Sync Delay	Planned
Test Subject Button	In progress

Rationale: Verify that the PIC embedded code converts the commanded state to the correct current. Motivated by DR 3.2, DR 3.3 and DR 3.4.

Procedure: Command state x and check that the output current is correct.

Risk Reduction: The ability to properly command the GVS system is vital to ensuring the safety of any test subject

Equipment: Laptop, USB cable, GVS PIC and DAC
Expected Results: Correct voltages being output

Central Processing System Testing

CPS	
CPS Command	Complete
CPS to GVS Comms	Planned
CPS to GVS Command	Planned
Sync Delay	**Planned**
Test Subject Button	In progress

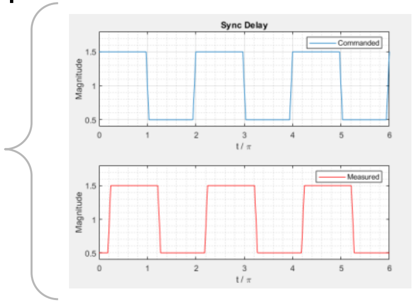
Equipment: Laptop, TCS Arduino, GVS PIC, associated cables. .
Expected Results: Delay between GVS and TCS is <100ms.

Rationale: Ensure synergy between GVS cue, and TCS cue. Motivated by DR 3.3. (<100ms))

Procedure: <u>Quantify time from signal command to actuation</u> for both GVS and TCS.

1. Commands at a determined period will be sent to GVS/TCS via the CPS.
2. The output waveform is phase shifted at the GVS/TCS and will be measured with an oscilloscope.
3. The delta between these two phases will be the ‘delay’ time.

Risk Reduction: Prevents possible disorientation Test subject.



Central Processing System Testing

CPS	
CPS Command	Complete
CPS to GVS Comms	In progress
CPS to GVS Command	In progress
Sync Delay	Planned
Test Subject Button	**In progress**

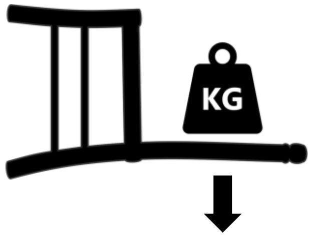
Equipment: Laptop,oscilloscope, GVS and TCS.
Expected Results: The button will terminate all operation of the system.

Rationale: Provides the test subject with a means to quickly and effectively terminate all cueing.

Procedure:: Test safety button within all modes of CHAIR operation.

Risk Reduction: Added layer of safety.

Tactile Cueing System Testing



TCS	
Seat Structural Test	**Planned**
Center of Gravity Test	Planned
Actuator Assembly Test	Planned
Actuator Performance Test	Planned

Rationale: Verify that the seat can support the forces imparted by the customer, specifically the weld between seat back and seat pan.

Procedure: Clamp the chair to a workbench so that the seat back is parallel to the ground. Load the face of the seat back with 5 times the expected force that will be applied to the seat back by the customer.

Risk Reduction: Structural failure

Expected Results: The seat will securely support the customer.
Models Validated: Structural model

Tactile Cueing System Testing

TCS	
Seat Structural Test	Planned
Center of Gravity Test	**Planned**
Actuator Assembly Test	Planned
Actuator Performance Test	Planned

Rationale: Verify that the chair will not tip over when being operated by customer

Equipment: Protractor

Procedures: Locate the angle of equilibrium of chair from vertical when tilted backwards, add weights until angle is at least 20 degrees from vertical

Expected Results: The chair will remain in a stable upright position.
Models Validated: Structural model
Risk Reduction: Rapid unplanned reorientation

Tactile Cueing System Testing

TCS	
Seat Structural Test	Planned
Center of Gravity Test	Planned
Actuator Assembly Test	**Planned**
Actuator Performance Test	Planned

Equipment: Caliper
Expected Results: The chair will remain in a stable upright position.
Models Validated: Actuator extension model
Risk Reduction: Actuator jam

Rationale: Verify that the actuators can properly actuate once assembled and attached to chair

Procedures: Extend to 3” and back 10 times. Extend to 3” in half inch increments and pause for 5 seconds at each extreme.

Expected Results: The actuator will be able to extend to full extension (3”) and back 10 times. The length from an external measurement and the actuator feedback at either extreme should both be within ⅛” of the commanded input and between each other.

Tactile Cueing System Testing

TCS	
Seat Structural Test	Planned
Center of Gravity Test	Planned
Actuator Assembly Test	Planned
Actuator Performance Test	**Planned**

Equipment: Dr. Clark's dummy
Models Validated: Anthropometric measurements, force-pressure model
Risk Reduction: Effective cueing, the subject will not be at risk for pain due to actuators

Rationale: Verify that actuator assembly applies commanded pressure to test subject

Procedures: Input representative cueing angles (2-15, increment 1) for 5 seconds each

Expected Results: The pressure at the minimum representative cueing angle (2) and at the maximum representative cueing angle (15) should be above 2.65 kPa 95% of the measured pressure profile and below 25 kPa.The commanded force should be within 10% of the force sensor output.

Galvanic Vestibular Stimulator Testing

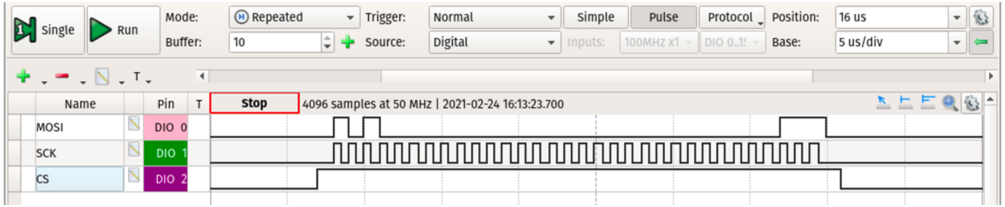
GVS	
Software & Component Testing	**In Progress**
Resistor “Dummy Load” Testing	Planned
Human Testing	Planned

Rationale: Verify software elements perform as expected, accept/reject CPS packets appropriately, and interface with GVS circuitry

Procedure: Use debugging tools, logic analyzers, and a multimeter to test UART, SPI, and DAC output

Risk Reduction: Reduced risk of project delays due to component failure

Expected Results: Outputs match the configuration bit settings and/or data sheets
Models Validated: GVS circuit model



Galvanic Vestibular Stimulator Testing

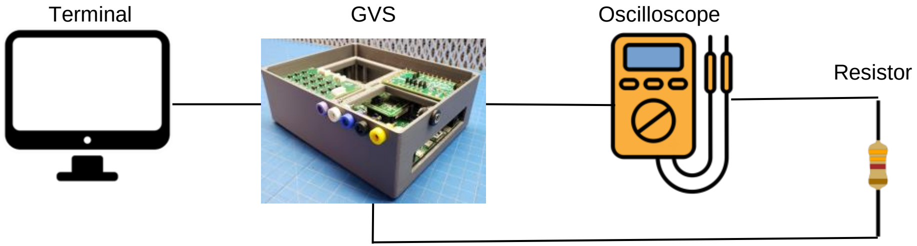
GVS	
Software & Component Testing	In Progress
Resistor "Dummy Load" Testing	**Planned**
Human Testing	Planned

Rationale: Determine timing and error to inform how the CPS will send signals & test protocols

Procedure: Use oscilloscope data to determine DAC error, Power-on Reset behavior, endurance behavior, without a human

Risk Reduction: Reduced risk of inappropriate current conditions

Expected Results: GVS controls currents to meet command values within +/- 1 LSB
Models Validated: GVS circuit model, DAC datasheet



Galvanic Vestibular Stimulator Testing

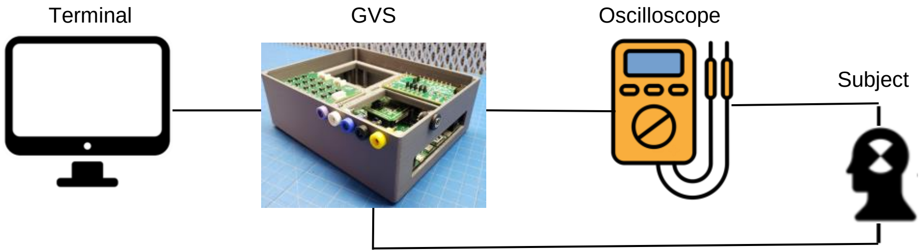
GVS	
Software & Component Testing	In Progress
Resistor “Dummy Load” Testing	Planned
Human Testing	**Planned**

Rationale: Verify that the system can drive currents with a human in the loop

Procedure: Attach electrodes to test subject, send current commands, analyze timing and re-analyze error values.

Risk Reduction: Reduced risk of failure to meet customer requirement of driving up to 4mA current

Expected Results: The GVS will command currents with performance identical to the resistor network
Models Validated: GVS circuit model



Full System: Functionality vs Performance

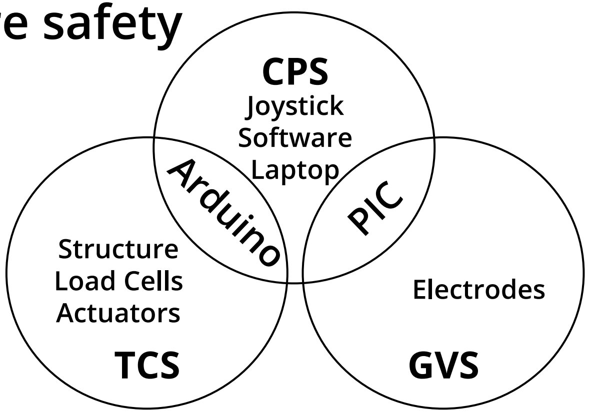
- Functionality
  - Conventional verification tests
  - Directly measurable quantities
  - Derived from models
- Performance
  - Limited scope due to human test subjects
  - Human perception can’t be measured directly
  - Variance between test subjects

Requirement Satisfaction

Levels of Success

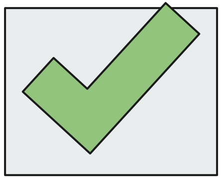
Full System Integration: Functionality

- Extension of subsystem testing
  - Test setup comes directly from high-level subsystem tests
  - Microcontrollers are each tested with two subsystems
  - Integration tests will focus on verifying full system communication
  - Measured quantities are used to verify all requirements
    - Force, current, lag time, safety stops
- All system tests will be performed twice to ensure safety

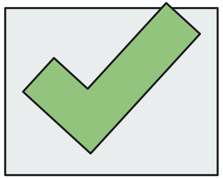


Full System Integration: Performance

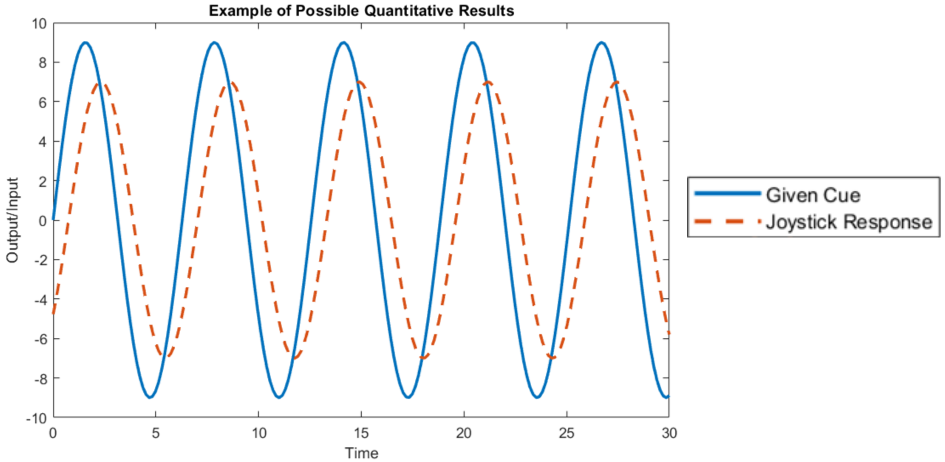
- Small sample size makes statistical validation inaccurate
- Full system performance will be shown through demonstration
- Human perception can’t be directly measured
    - Qualitative surveys will provide insight into subject perception
    - Recorded joystick data can provide quantitative data
        - Level 1: Joystick indication
        - Level 2: Joystick tracking
        - Level 3: Tilt nulling



Perceived Direction



Relative Magnitude



Budget

Procurement Status

Subsystem Procurement Breakdown					
Subsystem	**Received**	**Delivered**	**Pending**	**Backorder**	**Planned**
Galvanic Vestibular Stimulator (GVS)	25	0	4	0	0
Tactile Cueing System (TCS)	51	0	0	0	0
Central Processing System (CPS)	28	0	0	0	2
Total	**104**	**0**	**4**	**0**	**2**

Pending Items: Connectors/Fasteners for GVS, arrive this week
Planned Items: PCB housing materials, Full scale PCB, <1 week lead

All key items required to move forward with testing have been received

Budget Status

Subsystem Breakdown				
Subsystem	**Budget**	**Margin**	**Total Expenses**	**Remaining Budget**
Galvanic Vestibular Stimulator (GVS)	$ 775.00	$ 86.11	$ 772.97	$ 2.03
Tactile Cueing System (TCS)	$ 2,850.00	$ 316.67	$ 2,816.19	$ 33.81
Central Processing System (CPS)	$ 650.00	$ 72.22	$ 628.12	$ 21.88
Misc	$ 225.00	$ 25.00	$ 204.38	$ 20.62
Total	**$ 4,500.00**	**$ 500.00**	**$ 4,421.66**	**$ 78.34**

Concerns

- Massive failure of GVS or TCS could put us over budget
- If the electronics need a redesign we might not be able to get team shirts for expo

Questions

Backup Slides

CPS Test Path to DR 2.4

Joystick Comms Test	GVS Comms Test	TCS Comms Test	Joystick interference Test	TCS Safe Level Test	TCS Malicious Feedback Test
Verify that the CPS can read the joystick data	Establish UART Communication for the PIC and verify data sent & received.	Establish UART Communication for the Arduino and verify data sent & received.	Command a safe value but make it unsafe with joystick augmentation and ensure that it still terminates	Record feedback data from the Arduino (load cells) to verify force of actuation. Ensure it is within safe bounds.	Create unsafe feedback from the TCS load cells and ensure that the test terminates

CPS Command Test

Record the CPS output while commanding values higher than the allowed maximums. Ensure CPS does not command the in-apprortiate values.

DR 2.4

“The CPS will not instruct the TCS or the GVS to exceed the maximum allowed outputs described in requirements 2.1 and 2.3. (25 kPa, 4mA)”

CPS Test Path to DR 2.5

Joystick Comms Test → **Test Subject Button Test** → **Operator Button Test** → **DR 2.5**

- **Joystick Comms Test:** Verify that the CPS can read the joystick data.
- **Test Subject Button Test:** Verify functionality of the test subject's terminate button
- **Operator Button Test:** Verify functionality of the operator's terminate button
- **DR 2.5:** **"The CPS will be equipped with an emergency stop switch that will enable all functions to be terminated immediately."**

CPS Test Path to DR 3.1

TCS Comms Test	TCS Command Test	DR 3.1
Establish UART Communication for the Arduino and verify data sent & received.	Integrate Arduino software with the test hardware to fully test and tune a single actuator.	**"The TCS shall be provided with a method of communication to the Central Processing System."**

CPS Test Path to DR 3.2

TCS Comms Test → TCS Command Test → GVS Comms Test → GVS Commands Test → Sync Delay Test → DR 3.2

TCS Comms Test: Establish UART Communication for the Arduino and verify data sent & received.

TCS Command Test: Integrate Arduino software with the test hardware to fully test and tune a single actuator.

GVS Comms Test: Establish UART Communication for the PIC and verify data sent & received.

GVS Commands Test: Integrate PIC software with the test hardware to fully test and tune GVS.

Sync Delay Test: Record signal sent to TCS and signal sent to GVS and measure delay between equal states (will need to be less than 100 ms to allow for actuation)

DR 3.2: **"The CPS shall coordinate the TCS and GVS responses, such that the time delay between the TCS and GVS cues as experienced by the test subject is less than 100 ms."**

CPS Test Path to DR 3.3

Joystick Comms Test

Verify that the CPS can read the joystick data.

TCS Comms Test

Establish UART Communication for the Arduino and verify data sent & received.

TCS Command Test

Integrate Arduino software with the test hardware to fully test and tune a single actuator.

GVS Comms Test

Establish UART Communication for the PIC and verify data sent & received.

GVS Command Test

Integrate PIC software with the test hardware to fully test and tune GVS.

Joystick Delay Test

Record joystick input and CPS output and measure delay between command and cue (will need to be less than 200 ms to allow for actuation)

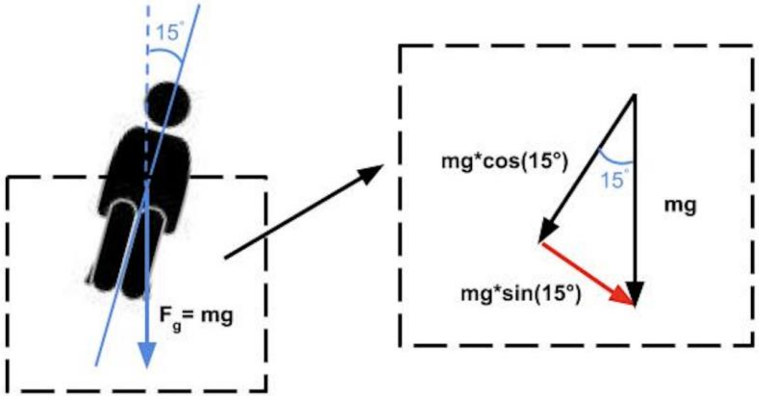
DR 2.4

"The CPS shall coordinate the hardware response such that the time delay from the joystick signal commanded by the test subject to the TCS and GVS cueing is within 200 ms."

CPS Test Path to DR 3.4

TCS Comms Test	TCS Command Test	GVS Comms Test	GVS Command Test	Sync Test	DR 2.4
Establish URAT Communication for the Arduino and verify data sent & received.	Integrate Arduino software with the test hardware to fully test and tune a single actuator.	Establish UART Communication for the PIC and verify data sent & received.	Integrate PIC software with the test hardware to fully test and tune GVS.	Use the user interface to command GVS and TCS magnitude and direction. Measure the microcontroller outputs to make sure they match up.num/descrip	**"The CPS shall incorporate a user interface allowing the controller to choose the magnitude and direction of tilt cued by the GVS and TCS systems."**

TCS Actuator Performance Representative Model



*representative

Max test subject weight: **215 lb**

Max side force applied:
$mgsin(15°)$ = **55 lb**

Side actuators must apply a total of 55 lb to mimic horizontal gravitational force during 15° roll angle

TCS Electronics Low Level Testing

Test	Status
Component Verification	incomplete
Single Actuator PCB Single Command	incomplete
Single Actuator PCB Controls Test	incomplete
Single Actuator	

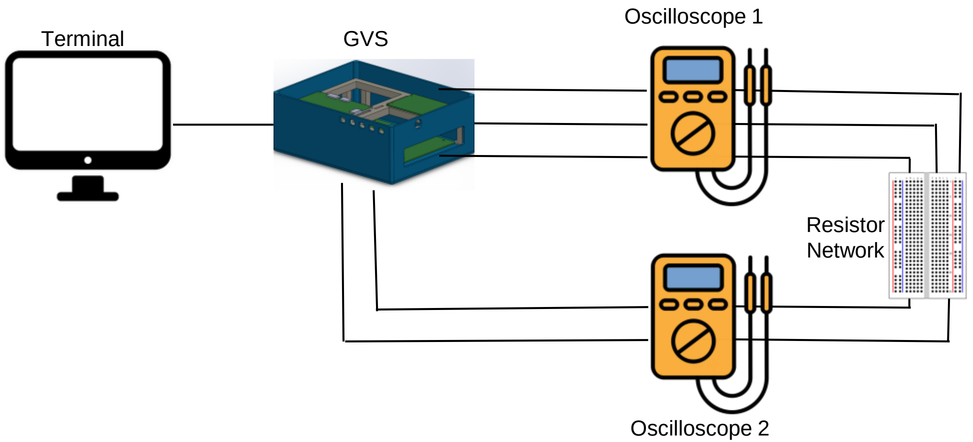
Galvanic Vestibular Testing

GVS	
Software & Component testing	In Progress
Resistor breadboard testing (dual-electrode)	Incomplete
Human testing (dual-electrode)	Incomplete
Reach goal testing (five-electrode)	**Incomplete**

Equipment: 2 Oscilloscopes, laptop, electrodes
Models Validated: Power circuit model
Risk Reduction: N/A, reach goal

Rationale: Verify our reach goal of subsystem capability to discreetly control 5 currents

Procedure: Repeat prior resistor and human testing with 5 electrodes connected through 5 channels across 2 oscilloscopes



Entire Gantt Chart Printout