SKADI
Test Readiness Review

2/21/2021, AERO N240

ASEN 4028-309 Team 9

Sponsor: USA Nordic Team

Faculty Advisor: Dr. Melvin Rafi

Team Members: Hunter Daboll, Maya Greenstein, Landon Nurge, Max Page, Joaquin Ramirez, Michael Schlittenhart, Julia Sheeran, Mary Sobernheim

Outline

- Overview
- Schedule
- Test Readiness
  - Synchronicity Test Campaign
  - Mechanical Tests
- Budget

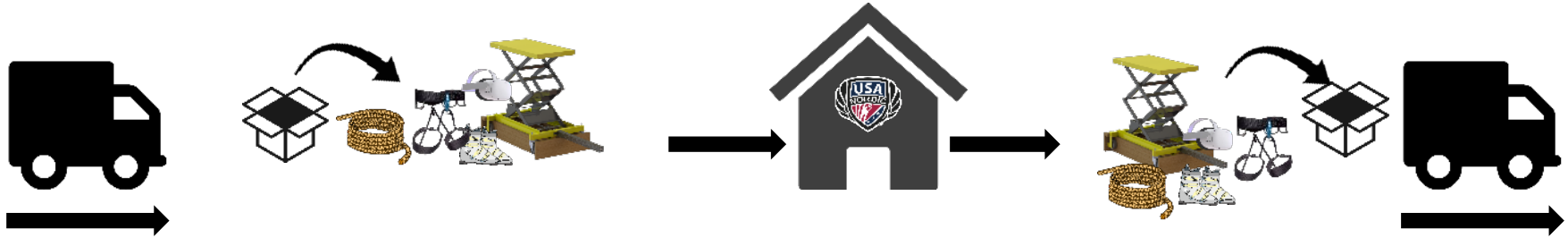
Overview

Section Outline

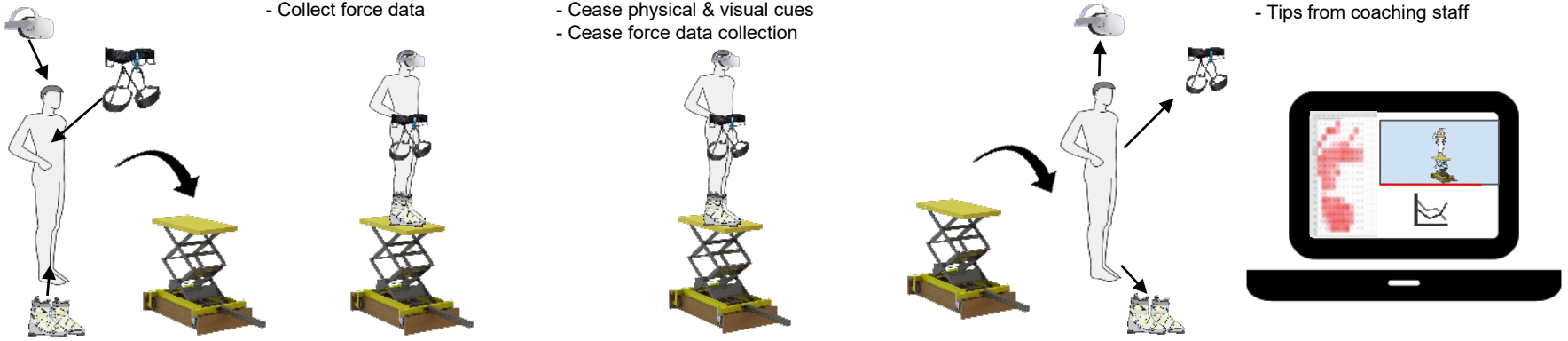
- ConOps
- FBD
- Full Design Solution
- CPEs

ConOps

1. Delivery & Assembly	**2-7. Used in Training**	8. Disassembly & Transport



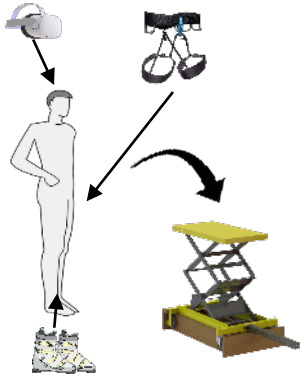
2. Don Gear & Mount	3. Run simulation	4. End Simulation	6. Dismount & Doff Gear	7. Provide Feedback
	- Apply physical & visual cues - Collect force data	- Catch user with belay system - Cease physical & visual cues - Cease force data collection		- Foot force distribution - Tips from coaching staff



Repeat Steps 2-7 until SKADI is moved to a different training facility

ConOps - Simulation

2. Don Gear & Mount



3. Run simulation

- Apply physical & visual cues
- Collect force data

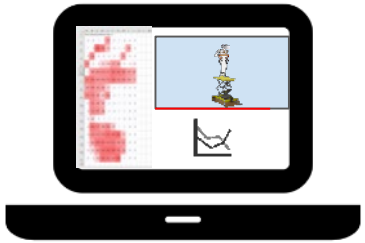
4. End Simulation

- Cease physical & visual cues
- Cease force data collection

6. Dismount & Doff Gear

7. Provide Feedback

- Foot force distribution
- Tips from coaching staff

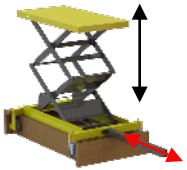


3.1 Start Visual Cues

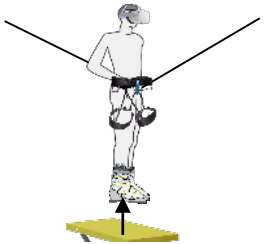
- Start of visual cues causes force data collection and physical cues to begin as well

3.2 Apply Physical Cues

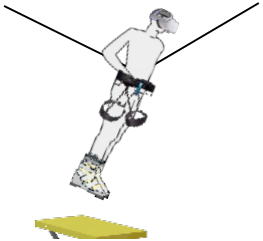
- Pneumatic actuator accelerates platform up and down



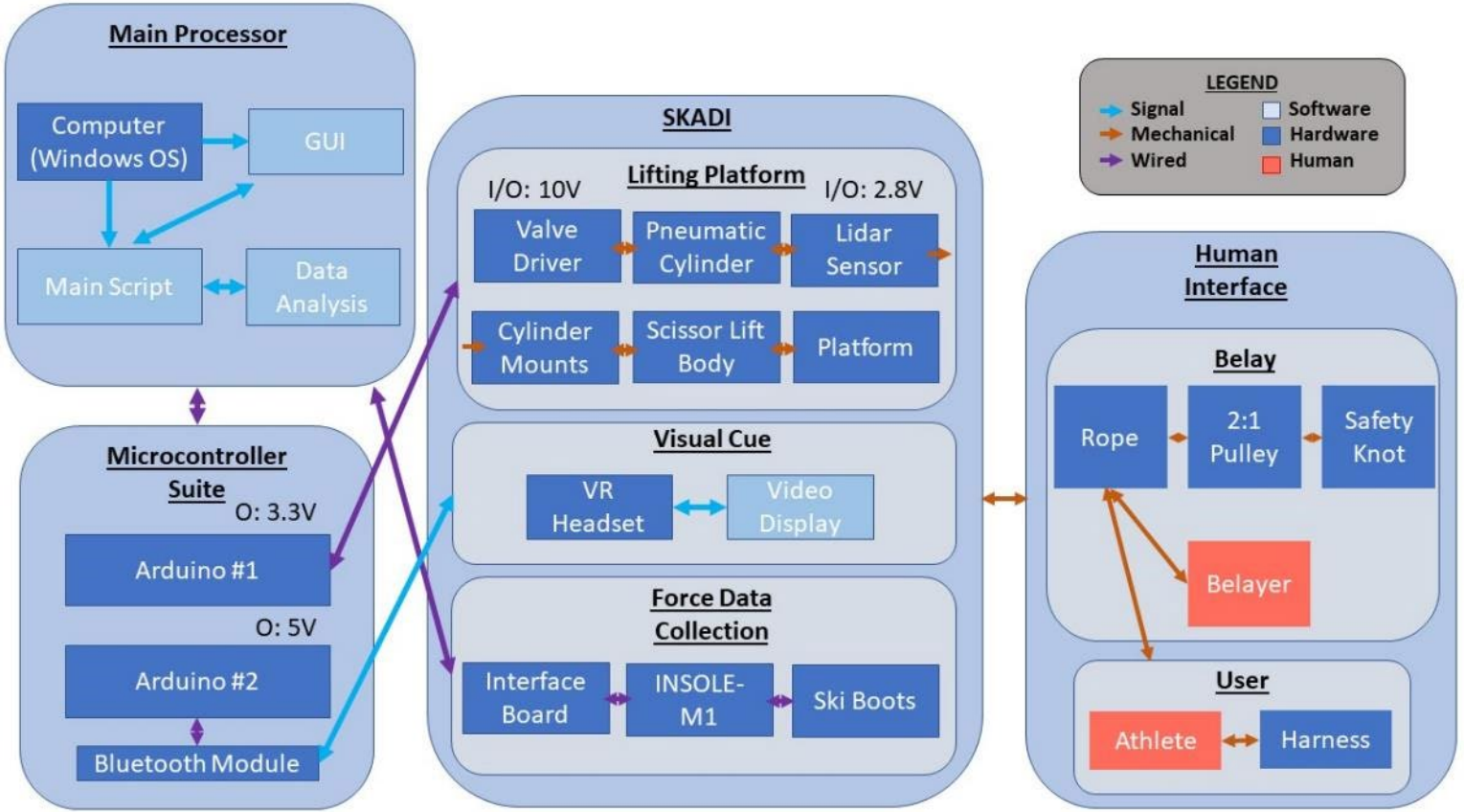
3.3 User Jumps



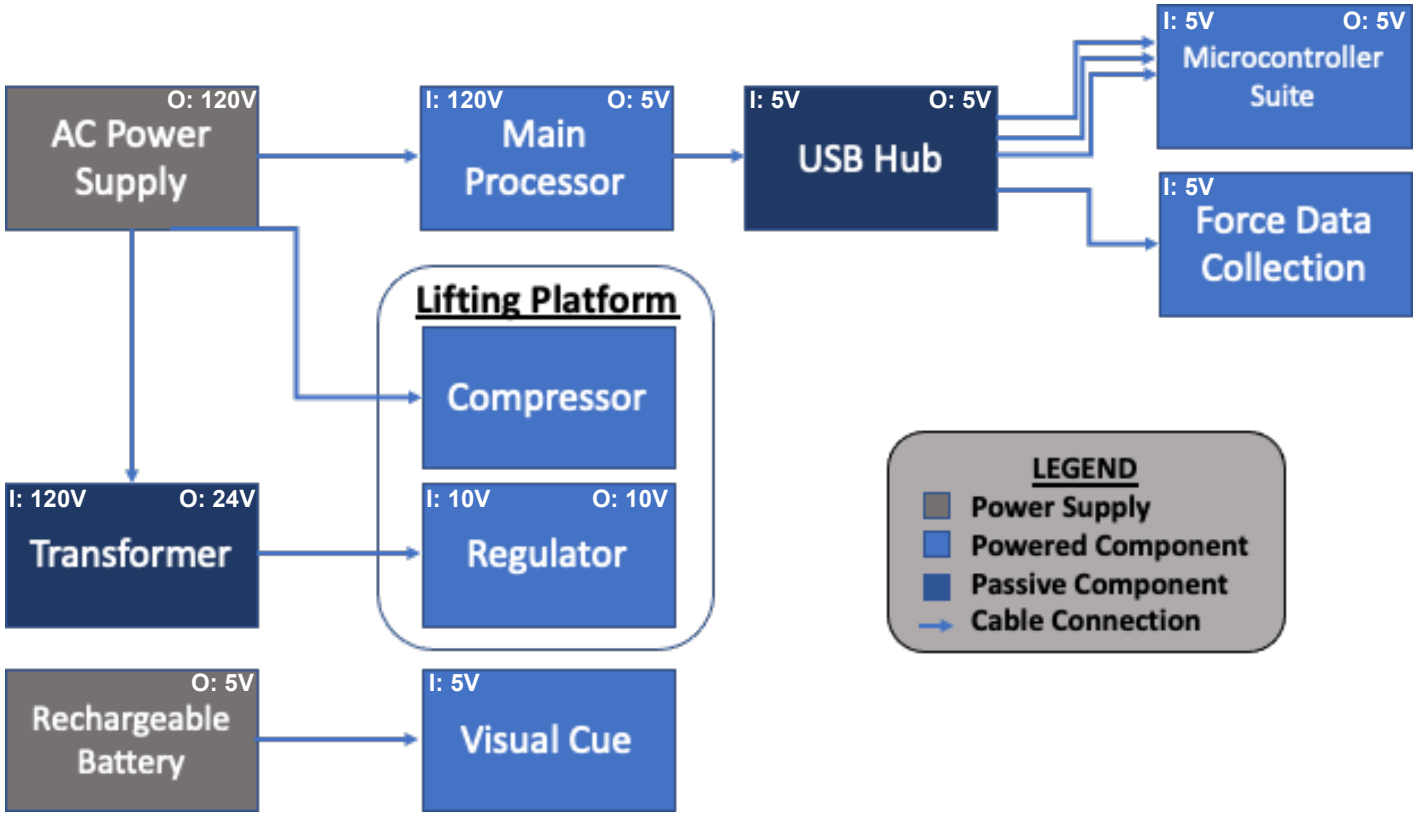
3.4 Catch User



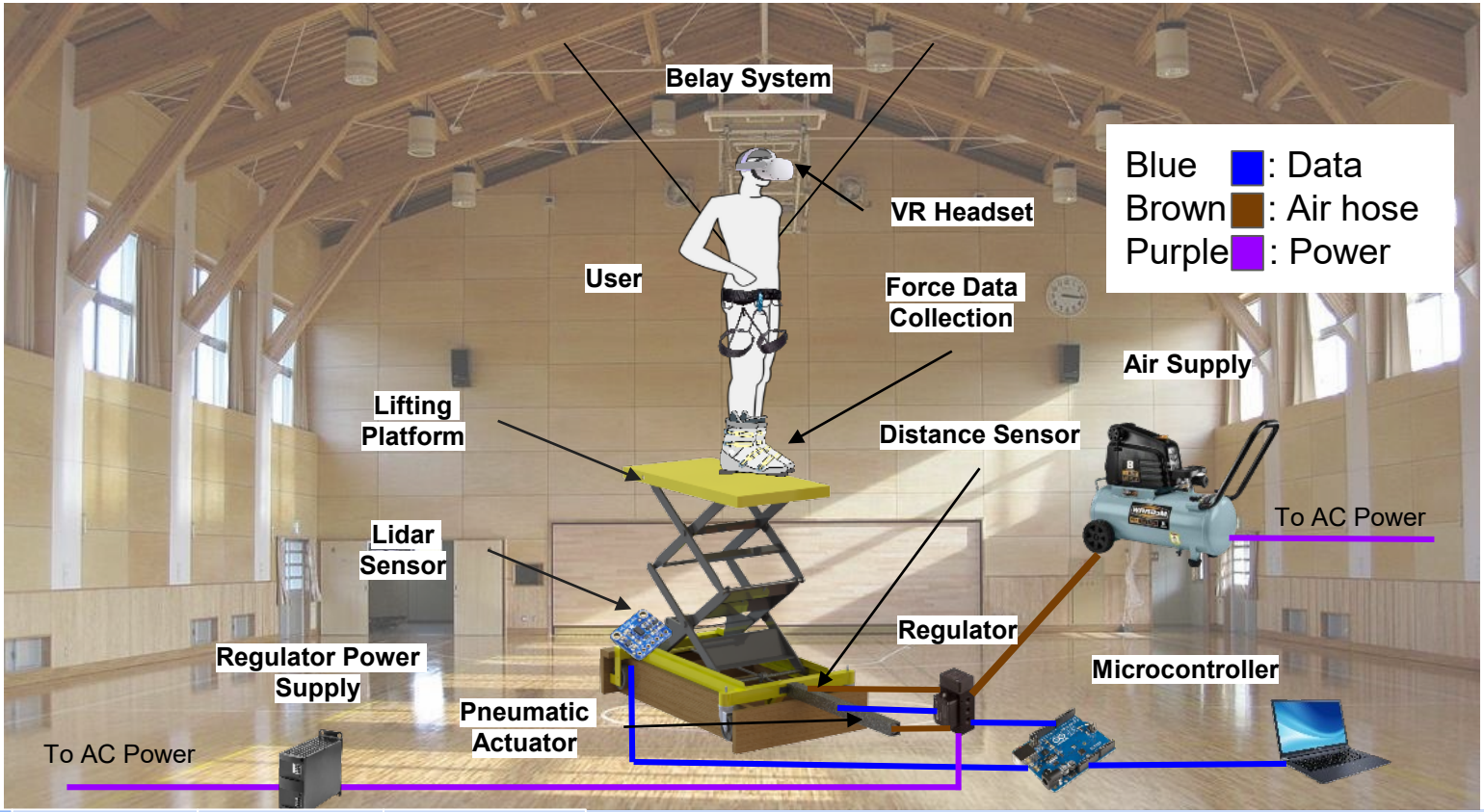
Functional Block Diagram



Power Supply



Full Design Solution



Critical Project Elements

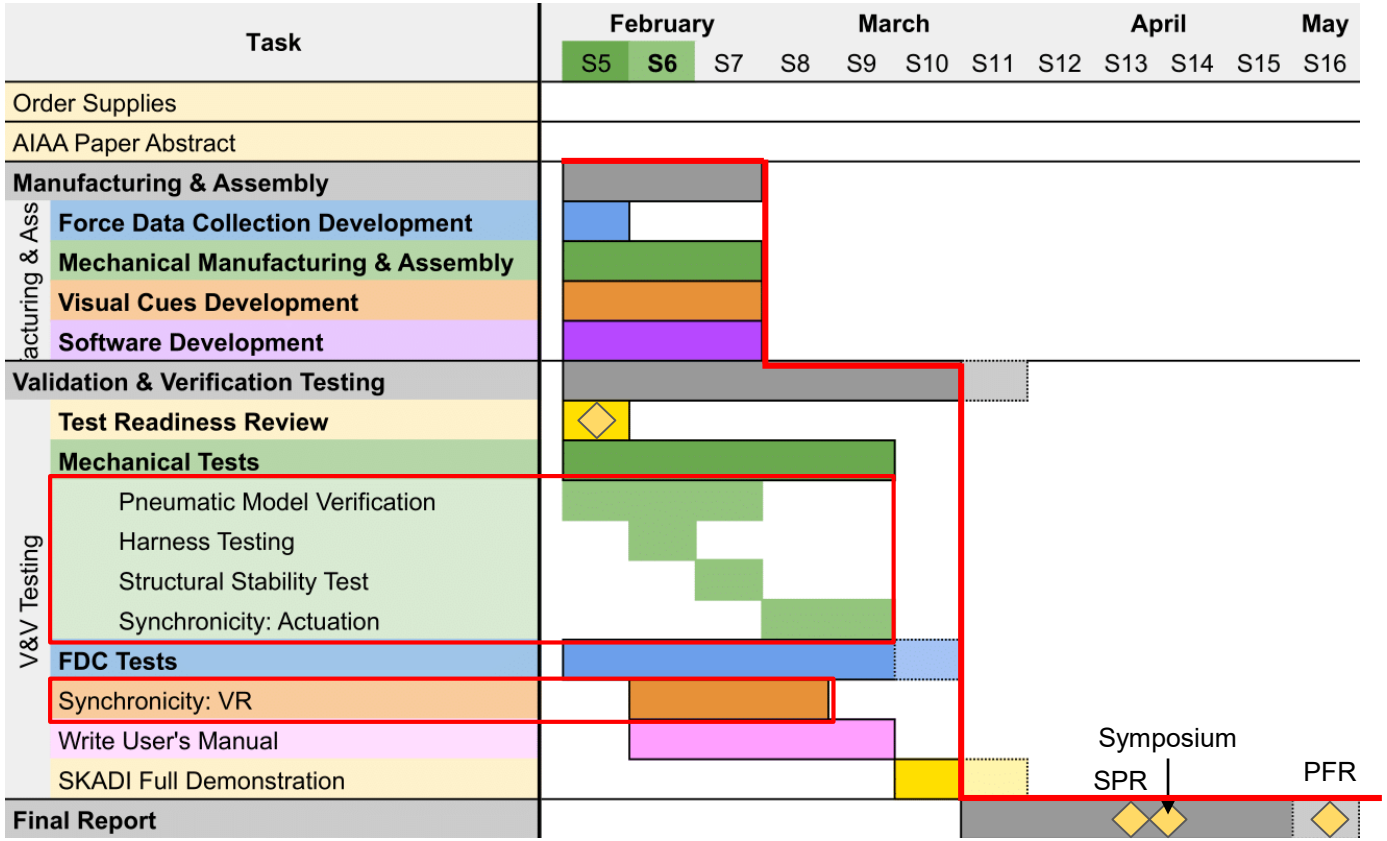
Func. Req.	CPE	Description
FR1, FR2, FR5	SYNC	The synchronization of the visual, foot force, and mechanical subsystems via software
FR2	GFORCE	The production of similar forces to those experienced by an athlete during ski jump takeoff
FR3, FR6	SAFE	The ability of SKADI to structurally withstand the maximum expected loads during simulation and keep the user safe
FR1, FR5	CUES	The ability of SKADI to provide visual cues and capture the force profile during simulation

Schedule

Section Outline

- Gantt Chart

Gantt Chart



- Schedule pushed back since CDR due to remote start and procurement delays
- All tests planned to be completed by Spring Break
- Full system demonstration by end of March
- April will be spent working on final project deliverables

Test Readiness

Section Outline

- Comprehensive Test List
- Mechanical Tests
- Force Data Collection Tests
- Synchronicity Test Campaign

Comprehensive Test List

- Mechanical Tests
  - **1. Dynamic Pneumatic Actuation System Verification**
  - **2. Belay System Validation**
  - **3. Structural Stability Test**
  - 4. Structural Load Test
- Force Data Collection Tests
  - **5. Kitronyx Calibration**
- Synchronicity Test Campaign
  - **6. SKADI Simulated Acceleration**
  - **7: SKADI Simulated Position**
- Pneumatic Actuator Tests
  - 8. Arduino Output
  - 9. Power Supply Component
  - 10. Distance Sensor Component
  - 11. Pressure Regulator Component
  - 12. Static Bore Position System
- Software Tests
  - 13. Oculus Application Success
  - 14. Oculus to PC Communication
  - 15. GUI Start Button Behavior
  - 16. GUI Status Updates
  - 17. Actuators Triggered

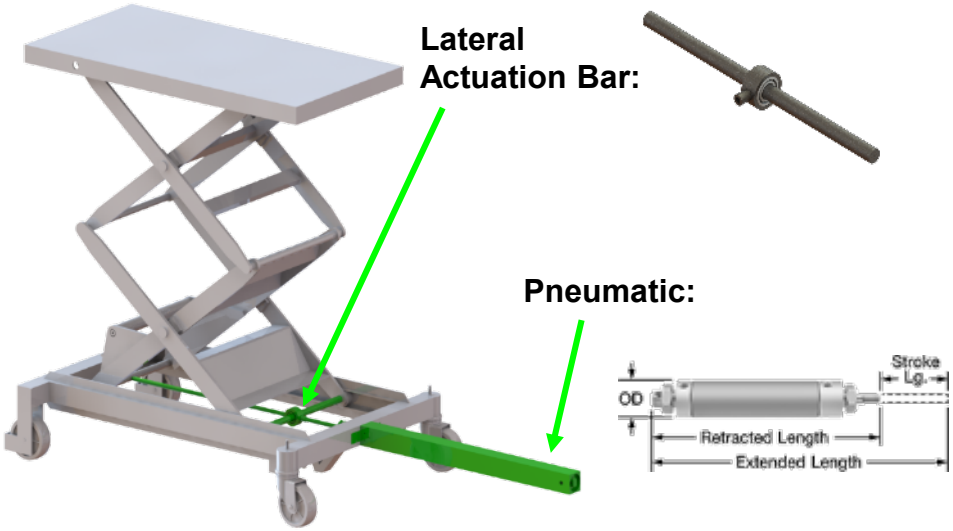
Mechanical Tests

Section Outline

- Dynamic Pneumatic Actuation System Verification
- Belay System Validation
- Structural Stability

Test 1 - Dynamic Pneumatic Actuation System Verification

FR 2: The simulator shall provide force and motion cues correlating to the phase in jump.

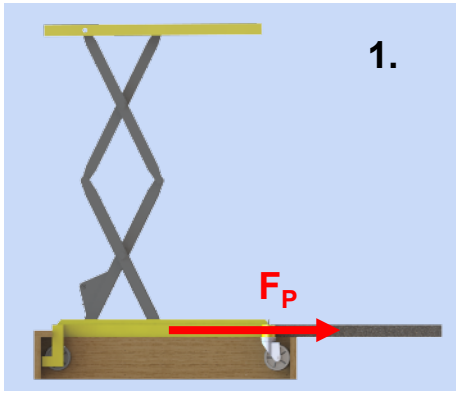


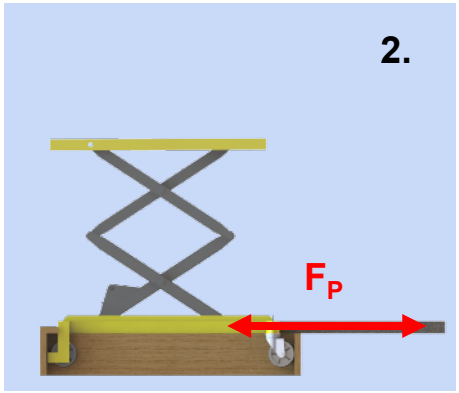
- **Objective**:
  - Test pneumatic system's ability to enact the actuation profile
- **Pass Criteria**:
  - Actual lift position is within 1 cm of desired throughout test
- **Required Hardware**:
  - Pressure regulator
  - Pneumatic cylinder
  - Air compressor
  - Pneumatic piping
  - Power supply
  - Arduino Due
  - Lidar sensor
  - Laptop
  - Lift

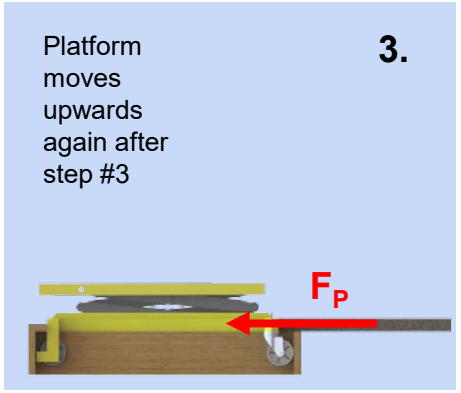
Test 1 - Dynamic Pneumatic Actuation System Verification

FR 2: The simulator shall provide force and motion cues correlating to the phase in jump.

- **Plan**:
  - Set up full pneumatic system and attach to lift
  - Input dynamic position profile to Arduino
  - Record lift position using lidar sensor
  - Compare desired to actual lift position throughout the test







Start Motion Profile

End Motion Profile

Downward Motion

Upward Motion

Downward Motion

Upward Motion

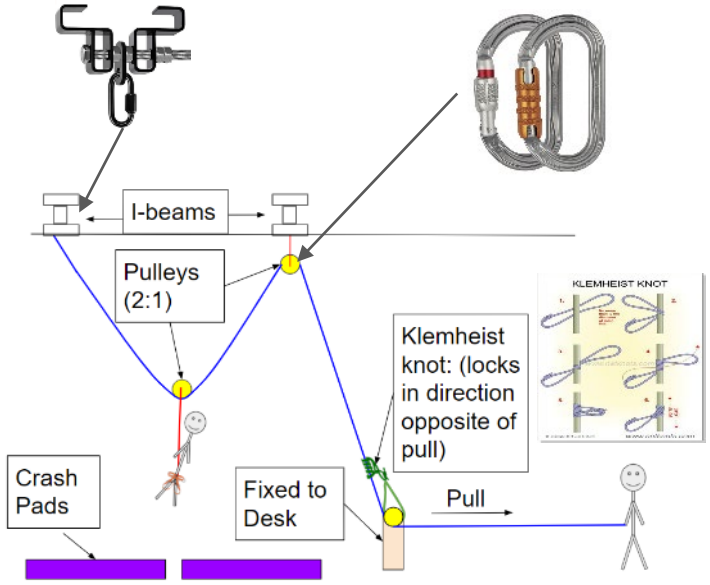
Downward Motion

Upward Motion

Test 2 - Belay System Validation

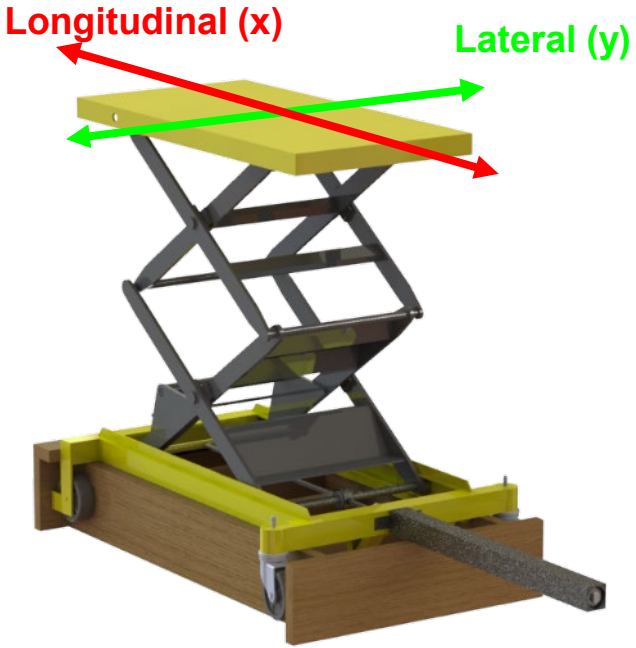
FR 6: The user will safely be brought to rest following the jump.

- **Objective**:
  - Test the belay system in order to verify the safety of the simulator
- **Plan**:
  - Attach I-beam clamps in Aero-140
  - Re-create belay system that will be delivered to customer (detailed in “Belay Test Plan” document)
  - One user and one “belayer” will simulate the jump and catching system
- **Required Hardware**:
  - I-beam clamps x2
  - 40m static 10mm rope
  - 12” 7mm cordelette
  - 16” 6mm cordelette
  - Locking carabiner x3
  - Climbing harness
  - Stopwatch
  - Crash Pads
- **Pass Criteria**:
  - User is caught by belay system following their jump
  - Belayer is able to pull in 11.8ft of slack within 2.5s
  - The user is able to report that they did not feel tension on the rope until after they jumped

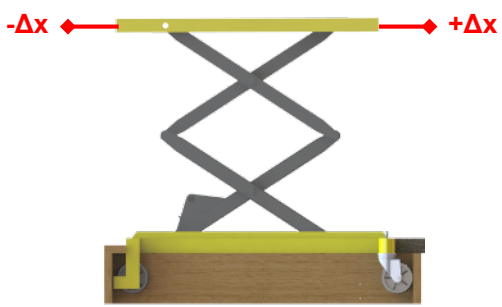


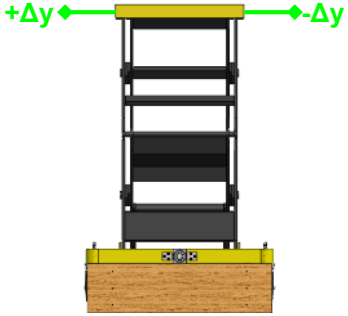
Test 3 - Structural Stability Test (Before and After)

FR 3: The simulator shall be able to support the forces generated when used by the full range of Nordic USA athletes.



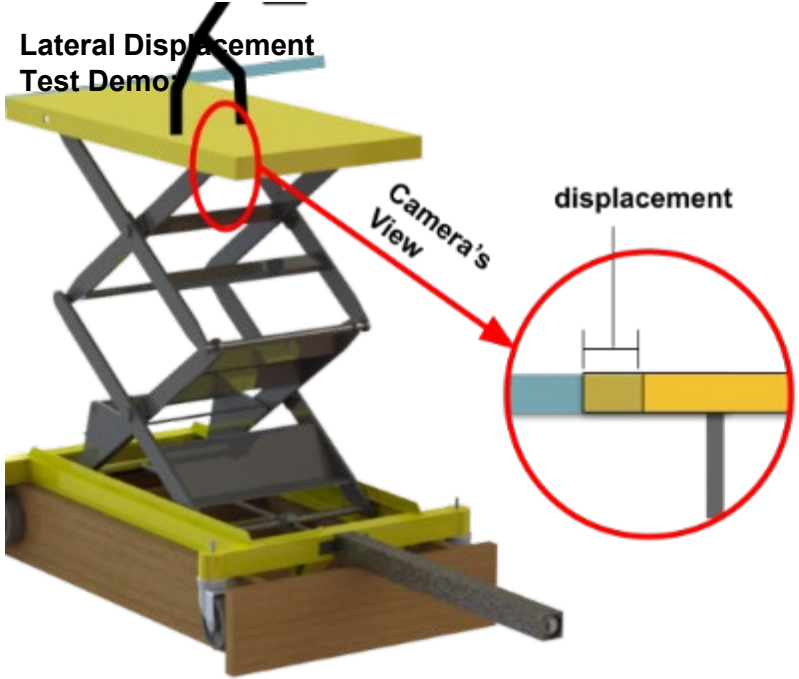
- **Objective**:
  - Ensure sideways platform movement isn't large enough to interfere with ski jump immersion
- **Pass Criteria**:
  - Maximum displacement does not exceed 5 cm either longitudinally or laterally





Test 3 - Structural Stability Test (Before and After)

FR 3: The simulator shall be able to support the forces generated when used by the full range of Nordic USA athletes.



- **Plan**:
  - Set up meter stick behind platform surface
  - Stand on lift at set height
  - Aggressively shift weight back and forth laterally and longitudinally
    - Main lateral displacement originates from loose platform attachment, not strut assembly
  - Record video and measure maximum displacement using meter stick
  - Repeat for at least three different platform heights
  - Perform full test before and after modifications
- **Required Hardware**:
  - Lift
  - Meter stick
  - Video camera

Force Data Collection Tests

Section Outline

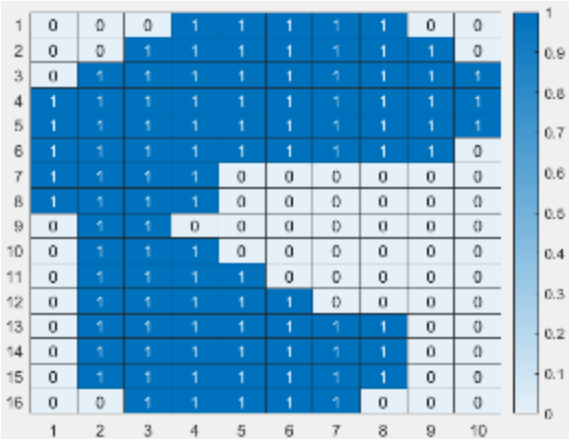
- Kitronyx Calibration

Test 5 - Kitronyx Calibration

DR5.4: The sensors shall accurately measure the forces exerted within 1% of bodyweight.

- **Objective**:
  - Obtain physical pressure values that correspond to the applied pressure by establishing a curve between a known applied force and the raw digital value
- **Plan**:
  - Apply known force to sensor
  - Measure ADC sum
  - Identify multiplier for the linear equation force = m*ADCsum
- **Required Hardware**:
  - PC
  - Kitronyx Sensor Suite
  - Weights
- **Pass Criteria**:
  - Multiplier is accurate within 1% of known applied force

View of ADC Sum in Snowforce



Ensure the pressure distribution of the force is equal

Synchronicity Test Campaign

Section Outline

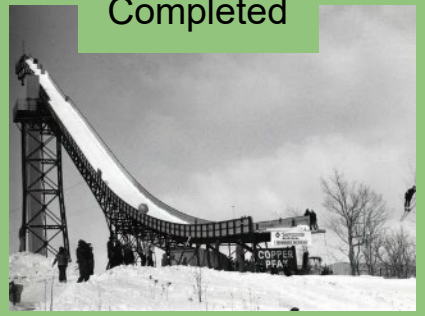
- Review of Campaign
- Setup
  - Data Capture
  - EOM Model Validation
- SKADI Simulated Acceleration
- SKADI Simulated Position

Synchronicity Test Campaign

FR1: The simulator shall provide visual cues correlating to the phase in jump.
FR2: The simulator shall provide force and motion cues correlating to the phase in jump.

- **Objective**:
  - Prove that visual cues and physical cues are in sync, and that both accurately correspond to motion on a real ski jump ramp
- **Plan**:

Completed

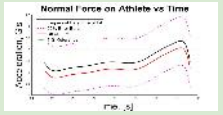


Component 1: Empirical Data on Real Ski Jump Slope

Begun

Component 2: Simulated Data in VR Experience

Upcoming

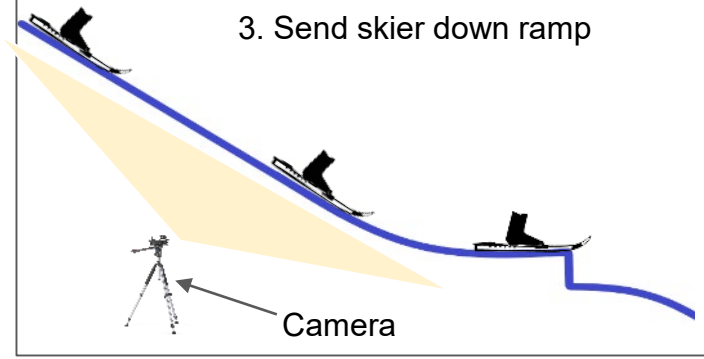


Component 3: Empirical Data on SKADI Training Simulator Platform

Setup - Data Capture

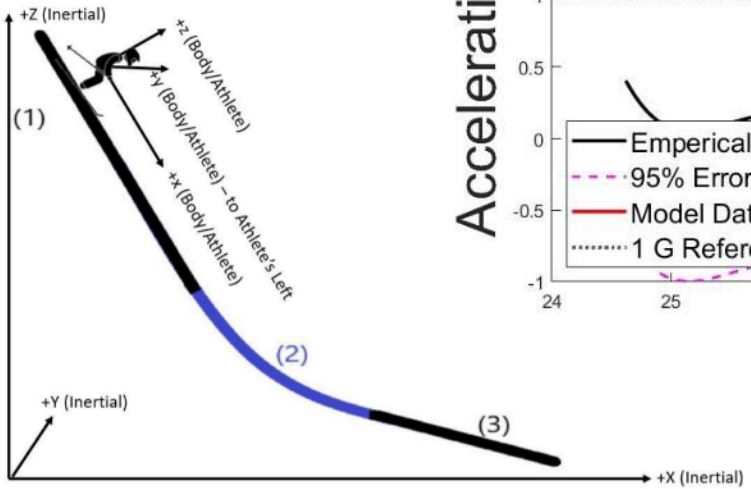
1. Set up camera to capture location data over time

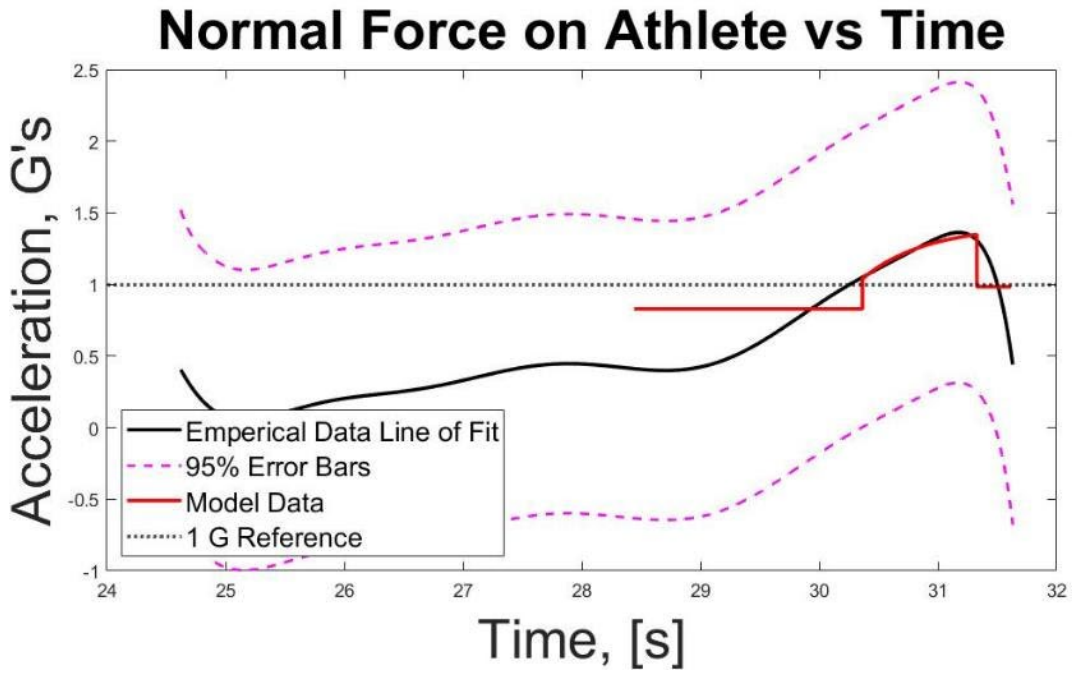
2. Strap accelerometer to ski boot on ski, begin data capture



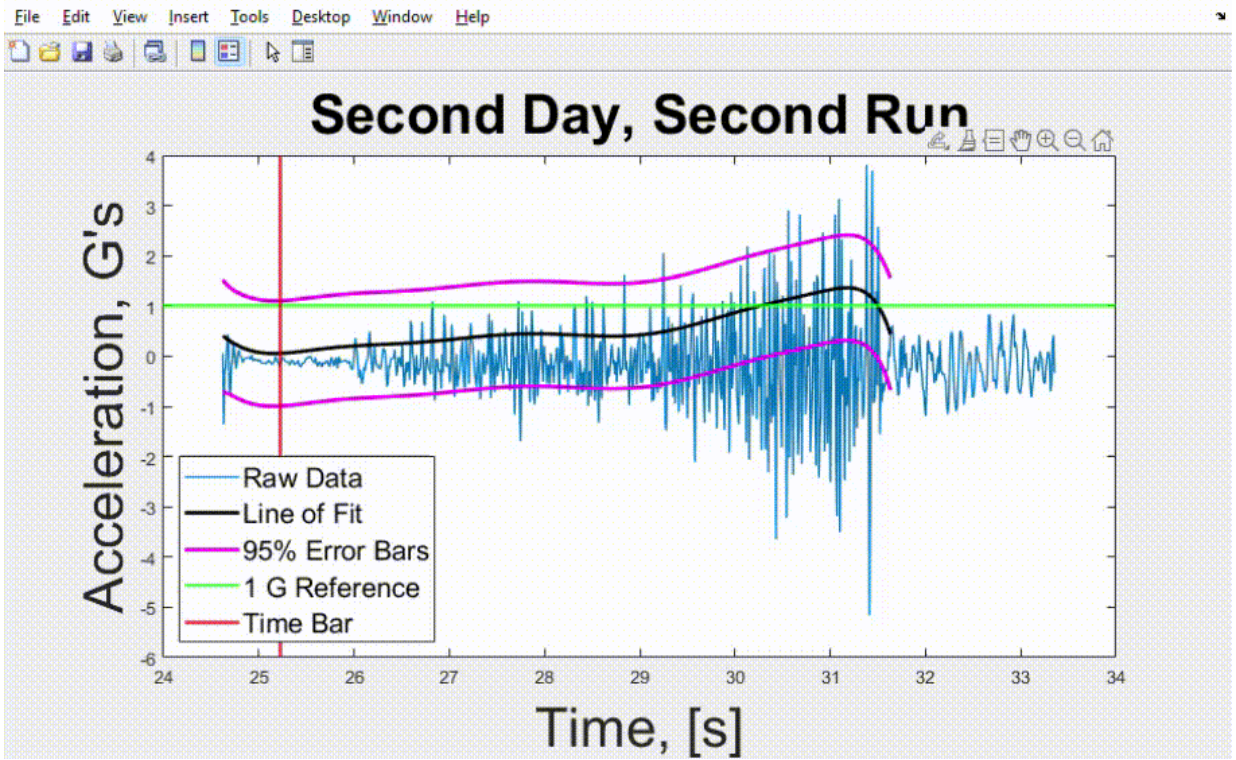
4. Export accelerometer data to .csv, synchronize to visual position data from camera

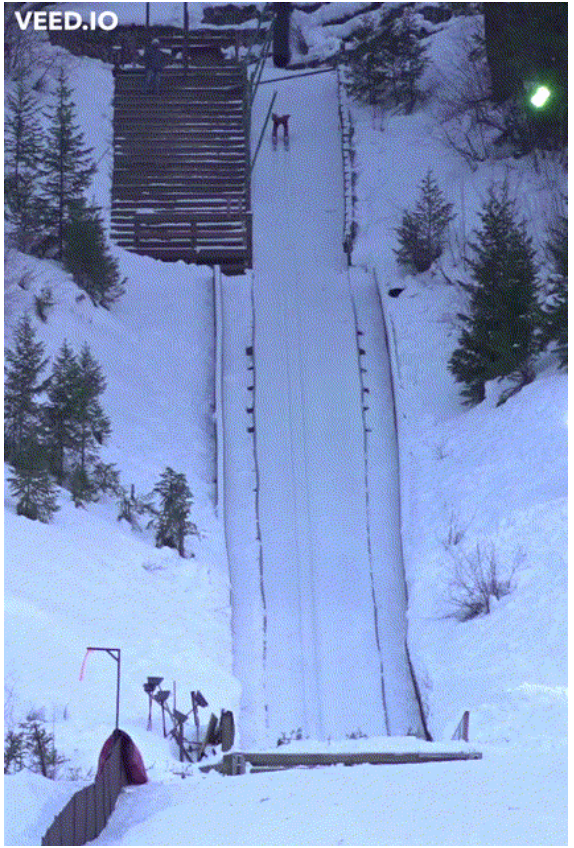
Setup - EOM Model Validation





Test 6 - SKADI Simulated Acceleration





Test 6 - SKADI Simulated Acceleration

DR2.1: Across the curved in run phase, the slope of force with respect to time that SKADI exerts will be within 20% of the slope of force with respect to time of a true ski jump ramp.

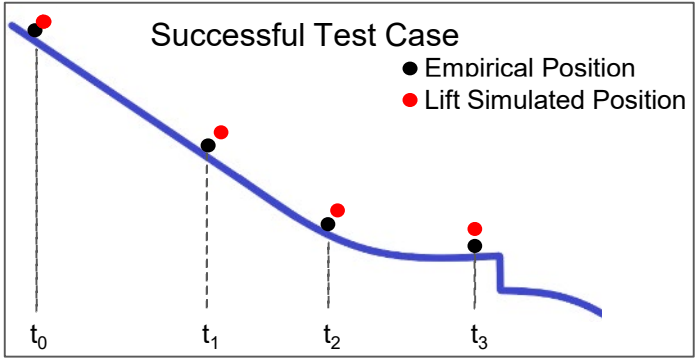
Objective:
- Prove SKADI lift simulated position over time matches those of ski jump

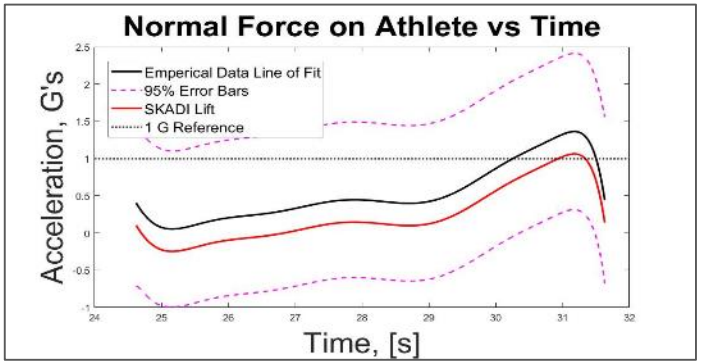
Plan:
- Compare accelerometer data vs time on lift to real ski jump

Required Hardware:
- Accelerometer & Data Logger

Test Location:
- AERO Machine Shop

Pass Criteria:
- At any time, slope of lift is within 20% of slope of jump





Test 7 - SKADI Simulated Position

Visual 360° Footage Capture/Testing

- Enables comparison of Empirical Footage to Unity Model
- Provides redundant visual display option

Test 7 - SKADI Simulated Position

FR1: The simulator shall provide visual cues correlating to the phase in jump.

DR1.1: The visual cue shall be synced to within ±300 milliseconds of the physical cue.

Objective:

- Prove VR simulated position over time matches that of ski jump

Plan:

- Output VR simulated position with timestamps at 3-4 points
- Compare timestamp of simulated positions to timestamp of true position from camera data
  - Camera footage from both
    - 360° 1st Person POV and
    - External camera footage

Required Hardware:

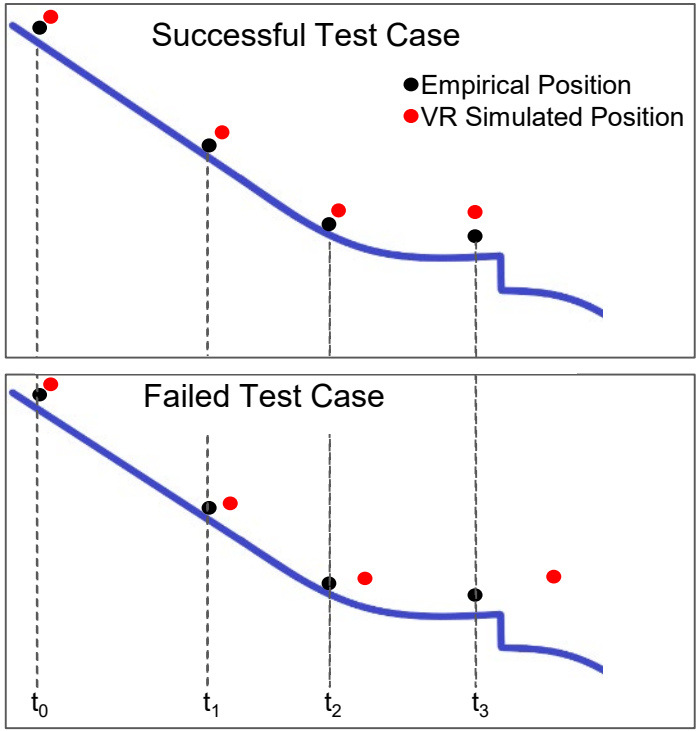
- VR Simulation

Required Measurements:

- VR simulated position with timestamps

Pass Criteria:

- At a given position, difference in timestamps is less than 300 milliseconds

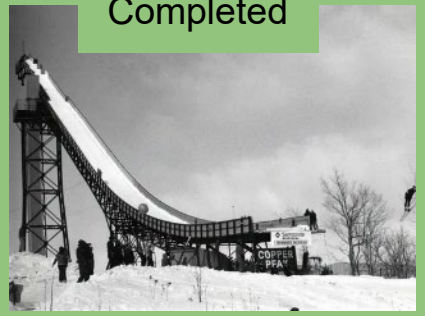


Recap of System Validation: Synchronicity Test Campaign

FR1: The simulator shall provide visual cues correlating to the phase in jump.
FR2: The simulator shall provide force and motion cues correlating to the phase in jump.

- **Objective**:
  - Prove that visual cues and physical cues are in sync, and that both accurately correspond to motion on a real ski jump ramp
- **Plan**:

Completed

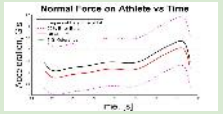


Component 1: Empirical Data on Real Ski Jump Slope

Begun

Component 2: Simulated Data in VR Experience

Upcoming



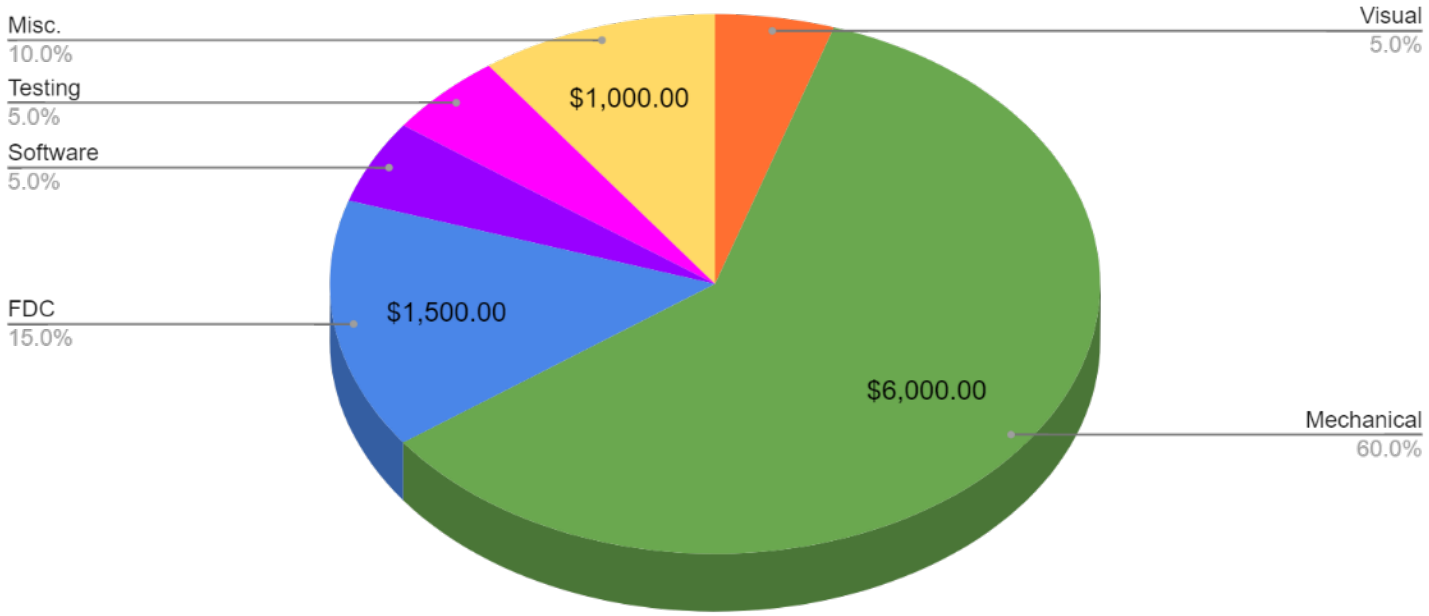
Component 3: Empirical Data on SKADI Training Simulator Platform

Budget

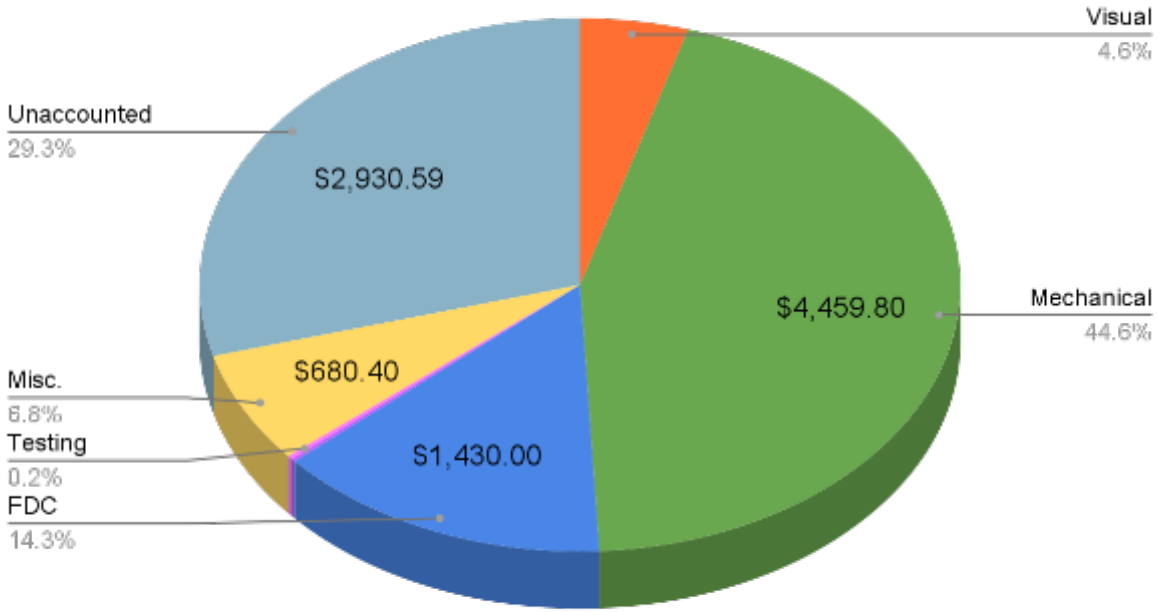
Section Outline

- Budget Breakdown
- Planned Costs
  - Steamboat Trip
- Completed Purchases
- Planned Purchases

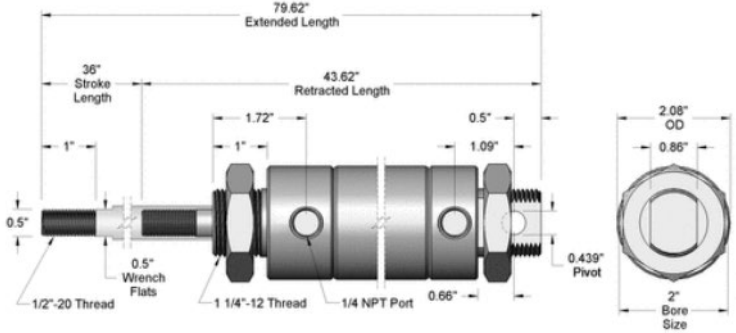
Budget Breakdown



Planned Costs



Big Ticket Items



$354.76 x 2 = $709.52

$428.00

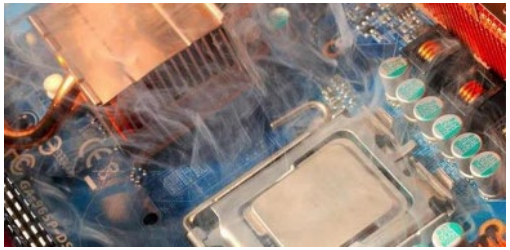
$994.00 x 2 = $1988

$1239.74

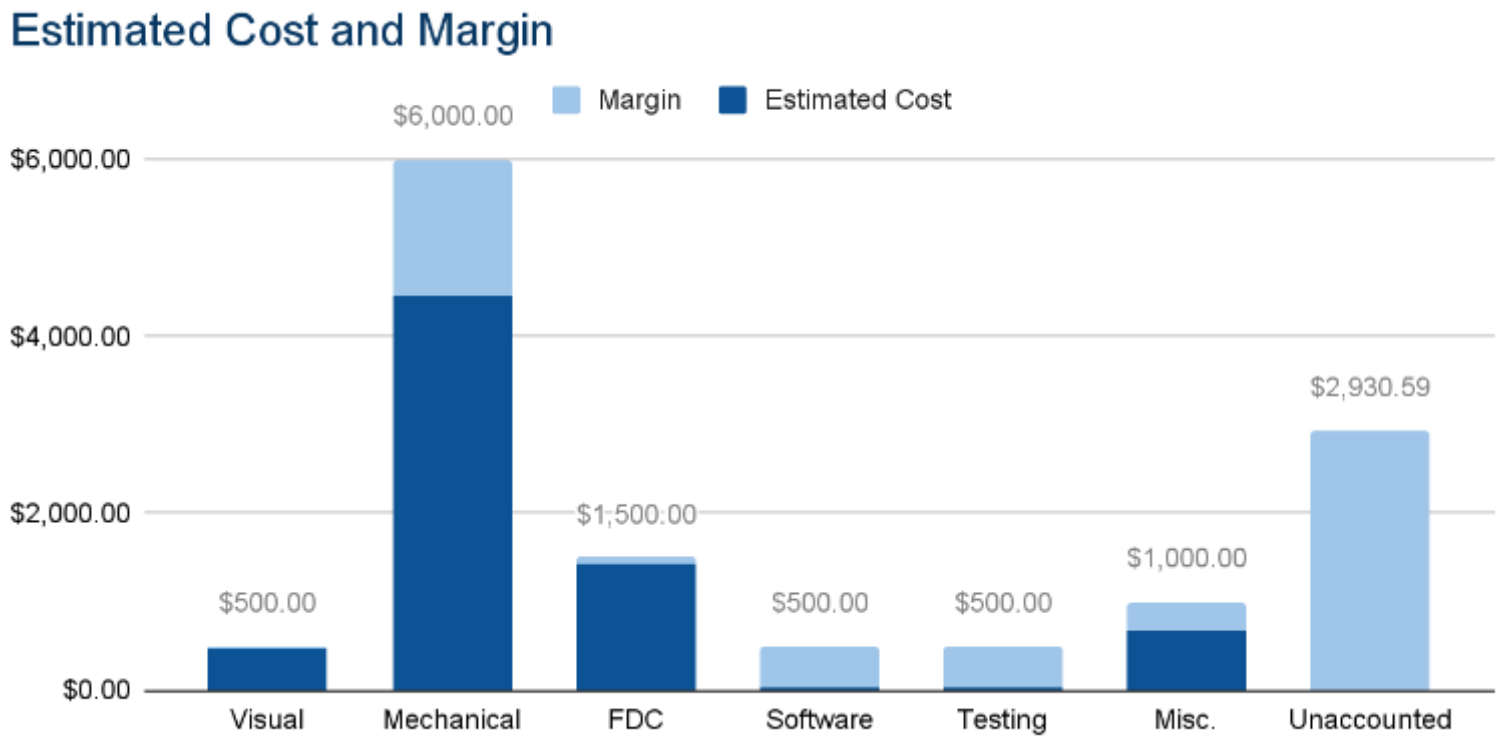
$1430.00

At Risk Items

- Pneumatic Cylinder - damage during testing
  - Have 2, system can work with one
- Pressure Regulator - damage during testing
  - Have 2, system can work with one
- Distance Sensors - fry during testing
  - Triple bought
- MOSFET
  - Double bought
- Power Supply - fry during testing
  - Double bought
- Custom Metal Pieces - miscut during fabrication
  - Bought extra length for margin of error



Remaining Budget



Steamboat Trip

	Overestimate	Source		Expected	Source
Number of Days	2			2	
Number of Attendees	3			3	
Steamboat Springs Meals and Incidentals	$79	https://wv		$50	https://wv
Steamboat Springs Lodging	$129	https://wv		$69	https://wv
Gas Price Per Gallon	$3.30	https://ga		$3.30	https://ga
Avg. MPG	24.9	https://wv		24.9	https://wv
Miles to Travel	280			280	
Total Per Diem	$208.00			$118.82	
Total Gas	$37.06			$37.06	
Gross Cost	$1,285.06			$749.98	

Completed Purchases

Direct Costs	October	November	December	Janurary	TOTAL
HiLetgo		$ 8.39			$ 8.39
Arduino			$26.28		$ 26.28
Unity			$19.00		$ 19.00
Oculus			$435.63		$ 435.63
Mcmaster-Carr			$ 910.89	$ 212.86	$ 1,123.75
Amazon			$ 56.92		$ 56.92
Apollo				$ 1,165.80	$ 1,165.80
Enfield				$ 2,119.49	$ 2,119.49
Adfruit					$ -
Vendor					$ -
MonthlyTotal Expenses	$ -	$ 8.39	$ 1,448.72	$ 3,498.15	$ 4,955.26

All items listed have been procured

Planned Purchases

Direct Costs	November	December	Janurary	February	March	April	May	TOTAL
Lowes					$ 48.98			$ 48.98
Arduino				$ 42.38				$ 42.38
GetMetals				$ 75.27				$ 75.27
Sparkfun				$ 0.95				$ 0.95
Amazon					$ 70.99			$ 70.99
REI					$ 263.26			$ 263.26
McGraw				$ 149.99				$ 149.99
Adafruit				$44.85				$ 44.85
Kitronyx	$ 1,430.00							$ 1,430.00
CU Boulder							$ 200.00	$ 200.00
MonthlyTotal Expenses	$ 1,430.00	$ -	$ -	$ 313.44	$ 383.23	$ -	$ 200.00	$ 2,326.67

Kitronyx sensors have been procured

Fall…… ($4955.26)

Spring……..($2326.67)

Steamboat…… ($749.98)

Remaining……..**$1968.09**

Acknowledgments

USA Nordic Team: Tim Tetreault, Jed Hinkley

SSWC: Karl Denney and the U18/U16 Ski Jumpers

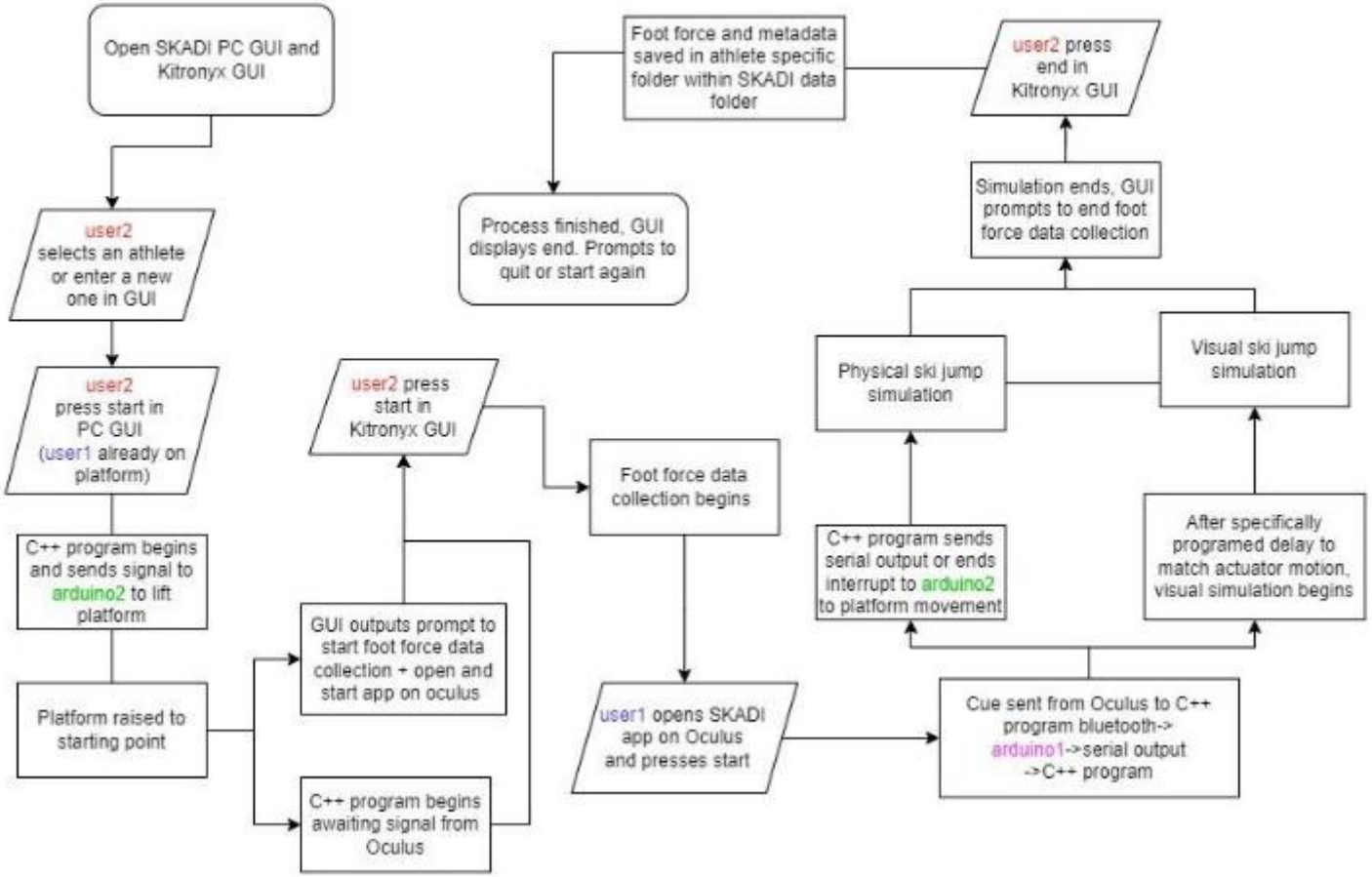
Faculty Advisor: Dr. Melvin Rafi

Additional Help: Trudy Schwartz, Matt Rhode, Bobby Hodgkinson, Jacqui Stang

Backup Slides

Section Outline

Supplier	Part Number	Part Name	Justification	Items per Order	Orders	Link	Unit Cost	Shipping	Total Cost
HiLetgo	HC-06 RS232	Wireless Bluetooth Serial RF Transceiver Module Bi-D	For Oculus control communication	1	1	https://www.ama	$8.39	$0.00	$8.39
Oculus		Oculus Quest 2 128 GB	Visual Cues Display Method	1	1	https://www.ocul	$299.00	$0.00	$299.00
Oculus		Quest 2 Elite Strap with Battery and Carrying Case	*Increases comfort, portability, battery life*	*1*	*1*	*https://www.ocul*	*$129.00*	*$0.00*	*$129.00*
Kiwi Design		Upgraded Elite Strap for Oculus Quest 2	*Increases comfort, portability*	*1*	*1*	*https://www.kiwi*	*$51.00*	*$0.00*	*$51.00*
Kitronyx	MP2513PLUS	Insole Sensor Kit	Force Data Collection method	1	1	https://www.kitro	$1,280.00	$150.00	$1,430.00
Arduino	A000066	Arduino Uno Rev3	Need arduino to interface with oculus	1	1	https://store-usa.	$19.55	$3.28	$22.83
~~McMaster-Carr~~	~~6498K586~~	~~Round Body Air Cylinder, Double Acting, Universal Mount, 2~~	~~Actuation of platform motion~~	~~1~~	~~2~~	~~https://www.mcm~~	~~$234.00~~		$0.00
McMaster-Carr	4952K743	Sensor-Ready Round Body Air Cylinder, Double Acting, 2" E	Same as 6498K586 but faster shipping, S	1	2	https://www.mcm	$354.76		$709.52
Unity		Arduino Bluetooth Plugin	Connect oculus to arduino	1	1	https://assetstore	$19.00	$0.00	$19.00
McGraw		8 Gallon 1.5 HP 150 PSI Oil-Free Portable Air Compre	Necessary for compressing and storing a	1	1	https://www.harb	$149.99	$0.00	$149.99
Adafruit	1528-1814-ND	Adafruit VL53L0X Time of Flight Micro-LIDAR Distanc	Used for feedback control loop of platfor	1	3	https://www.digik	$14.95		$44.85
Apollo	A-2010	Double Scissors Lift Table 1760lbs. 59" lifting height	COTS lifting platform, structure of mecha	1	1	https://www.apol	$949.00	$290.74	$1,239.74
Enfield	**S2-025-U-04**	S2 - HIGH-FLOW CYLINDER POSITIONING SYSTEI	Control system for pneumatic actuation	1	2	https://www.enfie	$994.00	$15.94	$2,003.94
Petzl	R39AO 040	Petzl Club 10mm 40m	Rope for belay	1	1	https://www.petz	$139.95	$10.00	$149.95
Trango		Trango Regulock HMS Screwlock	Carabiners for belay system	1	5	https://www.rei.c	$11.95		$59.75
REI		Accessory cord	Locking system	1	4	https://www.rei.c	$0.40	*$0.00*	$1.60
Black Diamond		Momentum Harness (Mens Medium)	Belay	1	1	https://www.blac	$51.96		$51.96
Lowes		2"x10"x8' Douglas Fir	Wooden Base	1	2	https://www.lowe	$14.17	$0.00	$28.34
Lowes		2"x8"x8' Douglas Fir	Wooden Base	1	2	https://www.lowe	$10.32		$20.64
Amazon		#8 2" Wood Screws	Wooden Base	100	1	https://www.ama	$12.99		$12.99
Mcmaster-Carr	1593N4	EPDM Air Hose with 1/4 x 1/4 NPTF Brass Male Fittin	Pneumatic hose	1	2	https://www.mcm	$18.97		$37.94
Mcmaster-Carr	1593N4	EPDM Air Hose with 1/4 x 1/4 NPTF Brass Male Fittin	Pneumatic hose	1	1	https://www.mcm	$20.41		$20.41
Mcmaster-Carr	7010K117	Power Supply, Single Phase, 100-240VAC Input, 24VI	Regulator power supply	1	2	https://www.mcm	$34.67		$69.34
Amazon		[2 Pack] USB 3.0 Cable, USB to USB Cable, USB A M	Data transfer for all systems	2	3	https://www.ama	$9.99	$0.00	$29.97
GetMetals		1018 Steel Round Bar	Actuator rod at bottom of lift	1	2	https://getmetals	$18.07	$0.00	$36.14
Lowes	~~241572~~	~~24-in x 36-in Cold Rolled Steel Solid Sheet Metal~~	~~Connect lift to actuator cylinder~~	~~1~~	~~2~~	~~https://www.lowe~~	~~$27.14~~	~~$0.00~~	$0.00
GetMetals		1018 2-1/2" steel rod - length: custom cut 1.2"	Sleeve to allow rolling of actuator rod	1	1	https://getmetals	$29.15	$0.00	$29.15
GetMetals		1018 .75" diameter 5" length	Perpendicular tube for thread	1	1	https://getmetals	$5.64		$5.64
Mcmaster-Carr	1641	1" load bearing	Allow sleeve to rotate freely	1	2	https://www.mcm	$24.98		$49.96
Mcmaster-Carr	91310A128	High-Strength Class 10.9 Steel Hex Head Screw	Connect cylinder holder to lift	10	2	https://www.mcm	$9.55		$19.10
Amazon		RIGERS Training Sandbags Heavy Duty	Secure belay system to gym floor	1	1	https://www.ama	$70.99	$0.00	$70.99
~~Amazon~~		~~Culler Strain Gauge Used in Mechanics Experiment fo~~	~~Testing sensors~~	~~4~~	~~4~~	~~https://www.ama~~	~~$20.99~~	$0.00	$0.00
Amazon		Loctite Threadlocker Red 271,0.20 fl. oz(209741)	Thread lock for joints	1	2	https://www.ama	$6.98		$13.96
Mcmaster-Carr	17715A44	Corner Bracket	Mounting Bracket for cylinder case	1	2	https://www.mcm	$6.24		$12.48
Sparkfun		100 Gain Opamp	Need 10 volts from arduino	1	1	https://www.spar	$0.95		$0.95
Mcmaster-Carr	6527K414	Steel Rectangular Tube (6ft)	Mount cylinder to lift	1	2	https://www.mcm	$53.69		$107.38
Balluff		Magnetic distance sensors	Used for feedback control loop of platform motion			https://www.ballu			$0.00
		Resistor	Step circuits for arduino						$0.00
Enfield		M8 5 pole cable	data cable for pneumatic control	1	2	https://www.enfie	$39.00	$17.25	$95.25
		Edison to free wire adapter	adapter for wall to power supply	1	1	https://www.parts	$3.98	$0.00	$3.98
Target		Iphone 11 protective case	empirical data collection for synchronicity	1	1		$39.99	$0.00	$39.99
Home Depot		dual camjam tie down system	secure phone to boot for empirical data c	1	1		$19.98	$0.00	$19.98
Home Depot		Velcro strap	secure phone to boot for empirical data c	1	1		$18.54	$0.00	$18.54
Home Depot		multipurose foam	secure phone to boot for empirical data c	1	1		$8.98	$0.00	$8.98
Amazon		I-beam clamp	Belay testing	1	2	https://www.ama	$19.99		$39.98
Sparkfun		mosfet switch kit	Voltage regulator for arduino	1	2	https://www.spar	$5.25		$10.50
Dell		Inspiron 15 3000 Laptop	Computer for simulation control	1	1	https://www.dell.	$279.99	$0.00	$279.99



user1 = athlete performing the simulation

user2 = coach/person controlling simulation and attached to harness

arduino1 = arduino attached to bluetooth receiving signal from Oculus

arduino2 = arduino sending voltages to pneumatics

Mechanical Tests

Section Outline

- Structural Load Test

Test 4 - Structural Load Test (Before and After Modification)

FR 3: The simulator shall be able to support the forces generated when used by the full range of Nordic USA athletes.

- **Objective**:
  - Verify lifting structure can support full expected load
- **Plan**:
  - Raise lift to a specified height
  - Place a weight on the platform
  - Incrementally increase weight until 600 lbs or plastic deformation occurs
  - Perform test at lowest and highest heights, as well as height corresponding to struts angled at 45 degrees
- **Required Hardware**:
  - Lift
  - 600 lbs of weights
- **Pass Criteria**:
  - Lift does not plastically deform at any point during testing process

Pneumatic Tests

Section Outline

- Arduino Output
- Power Supply Component
- Distance Sensor Component
- Pressure Regulator Component
- Static Bore Position System

Test 8 - Arduino Output

FR 2: The simulator shall provide force and motion cues correlating to the phase in jump.

- **Objective**:
  - Ensure the Arduino can output the correct analogue signal from a DAC port
- **Plan**:
  - Connect the Arduino to a computer via USB
  - Upload an analogue voltage profile to the Arduino
  - Execute the program and record the voltages from pin DAC1 using pin A1
  - Compare desired and measured voltages
- **Required Hardware**:
  - Arduino Due
  - Jumper wire
  - Laptop
  - USB cord
- **Pass Criteria**:
  - The Arduino is measured to output the correct analogue voltage profile, ok if amplitude is scaled down

Test 9 - Power Supply Component

FR 2: The simulator shall provide force and motion cues correlating to the phase in jump.

- **Objective**:
  - Verify the power supply can generate the necessary voltage for our system
- **Plan**:
  - Connect power supply to wall outlet using edison to bare wire adapter
  - Measure output voltage using electronics lab multimeter
- **Required Hardware**:
  - Power supply
  - Edison to bare wire adapter
  - Multimeter
- **Pass Criteria**:
  - The output maintains a DC voltage above 12V

Test 10 - Distance Sensor Component

FR2: The simulator shall provide force and motion cues correlating to the phase in jump.

- **Objective**:
  - Verify the lidar sensor can accurately measure distance in the intended environment
- **Plan**:
  - Connect lidar sensor to arduino
  - Place lidar sensor under lift
  - Simultaneously start reading lidar measurements and start timer on laptop
  - Move a reflector to 3 set positions at set times
  - Analyze lidar output accuracy and latency
- **Required Hardware**:
  - Lidar sensor
  - Arduino Due
  - Laptop
  - Meter stick
  - 1 piece of white printer paper
  - Lift
- **Pass Criteria**:
  - Lidar sensor measures distance to within 1 cm

Test 11 - Pressure Regulator Component

FR 2: The simulator shall provide force and motion cues correlating to the phase in jump.

- **Objective**:
  - Ensure pressure regulator can move the cylinder rod
- **Plan**:
  - Set up pneumatic system excluding load and analogue input
  - Vary input voltage between 0-10V
  - Record change in rod position between each voltage application
- **Required Hardware**:
  - Pressure regulator
  - Pneumatic cylinder
  - Air compressor
  - Pneumatic piping
  - Power supply
  - Arduino Due/ Voltage Boost Equipment
  - Laptop
  - Meter stick
- **Pass Criteria**:
  - Pneumatic rod position moves according to applied voltage level

Test 12 - Static Bore Position System (Unloaded/Loaded)

FR 2: The simulator shall provide force and motion cues correlating to the phase in jump.

- **Objective**:
  - Test pneumatic system's ability to maintain a static position.
- **Plan**:
  - Set up full pneumatic system (not connected to lift)
  - Input constant voltage to pressure regulator
  - Use meter stick to record position of pneumatic rod before and after voltage application
- **Required Hardware**:
  - Pressure regulator
  - Pneumatic cylinder
  - Air compressor
  - Pneumatic piping
- **Pass Criteria**:
  - Desired position of pneumatic rod is accurate within 1 cm after voltage application

  - Reset pneumatic system and connect to lift
  - Input constant voltage to pressure regulator
  - Use meter stick to record position of pneumatic rod before and after voltage application

  - Power supply
  - Arduino Due
  - Lidar sensor
  - Laptop
  - Meter stick
  - Lift

Software Tests

Section Outline

- Oculus Application Success
- Oculus to PC Communication
- GUI Start Button Behavior
- GUI Status Updates
- Actuators Triggered

Test 13 - Oculus Application Success

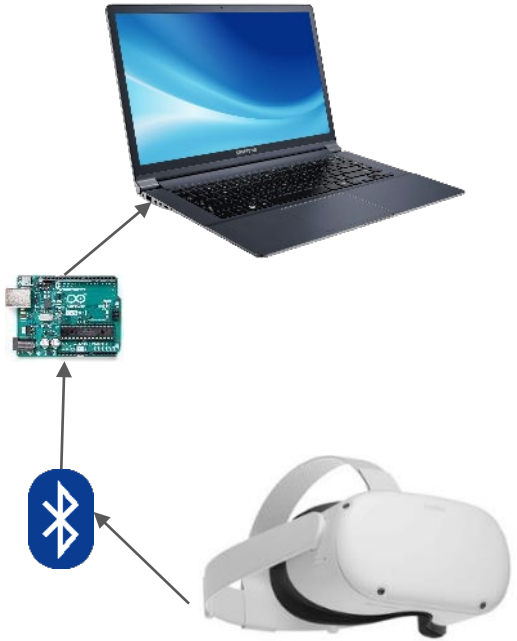
FR 1: The simulator shall provide visual cues correlating to the phase in jump.

- **Objective**:
  - Oculus Quest 2 app internally behaves as expected
- **Plan**:
  - Upload app to Oculus using Oculus Developer Hub
  - Open app, should show a start menu
  - Press start on menu
- **Required Hardware**:
  - Oculus Quest 2
- **Pass Criteria**:
  - When start is pressed the view should transition to a sk
    jump

Test 14 - Oculus to PC Communication

FR 1: The simulator shall provide visual cues correlating to the phase in jump.

- **Objective**:
  - Oculus Quest 2 can successfully send command to a PC via bluetooth + arduino
- **Plan**:
  - Have C++ program output signal when it receives bluetooth cue
  - 2 people - one on Oculus and one by PC
  - Have person on Oculus open app and press button to connect
- **Required Hardware**:
  - PC
  - Oculus Quest 2
- **Pass Criteria**:
  - The PC will receive the signal and send an output right after the button is pressed



Test 15 - GUI Start Button Behavior

FR 1: The simulator shall provide visual cues correlating to the phase in jump.

- **Objective**:
  - Start in GUI triggers C++ executable
- **Plan**:
  - Have C++ program output signal when it receives start cue
  - Open GUI and terminal simultaneously
  - Press button on GUI
- **Required Hardware**:
  - PC
- **Pass Criteria**:
  - C++ program outputs as expected when GUI is triggered

Test 16 - GUI Status Updates

FR 1: The simulator shall provide visual cues correlating to the phase in jump.

- **Objective**:
  - GUI status updated appear at the right times
- **Plan**:
  - Run through all steps of GUI (actuators need not be connected)
  - Check status updates as different aspects are being executed
- **Required Hardware**:
  - PC
  - OQ2
- **Pass Criteria**:
  - The status updates match up with the correct stage of the simulation

Test 17 - Actuators Triggered

FR 1: The simulator shall provide visual cues correlating to the phase in jump.

- **Objective**:
  - Actuators begin motion when arduino controlling receives command
- **Plan**:
  - Set up actuator to arduino connection
  - Run C++ code that should start actuators with a specified signal
- **Required Hardware**:
  - PC
- **Pass Criteria**:
  - Actuators start moving