***Skadi**, the Norse goddess of skiing*

SKADI Preliminary Design Review

10/12/2021, AERO 120

ASEN 4018-012 Team 9

Sponsor: USA Nordic Team **Faculty Advisor**: Dr. Melvin Rafi

Presenters: Hunter Daboll, Landon Nurge, Max Page, Joaquin Ramirez, Michael Schlittenhart, Julia Sheeran, Mary Sobernheim

Additional Team Members: Maya Greenstein, Max Page

Outline

- Project Description
- Evidence of Baseline Feasibility
  - Critical Elements
  - Feasibility Analyses
    - Visual
    - Mechanical
    - Force Data Collection
- Status Summary & Future Work

SKADI = Ski jump Athletic Development Interface

Project Description

Presenters: Mary Sobernheim, Joaquin Ramirez, Hunter Daboll

Section Outline

- What is Nordic Ski Jumping?
- Project Motivation
- Mission Statement
- Functional Requirements
- ConOps (Static)
- Baseline Design
- ConOps (Animated)
- Functional Block Diagram

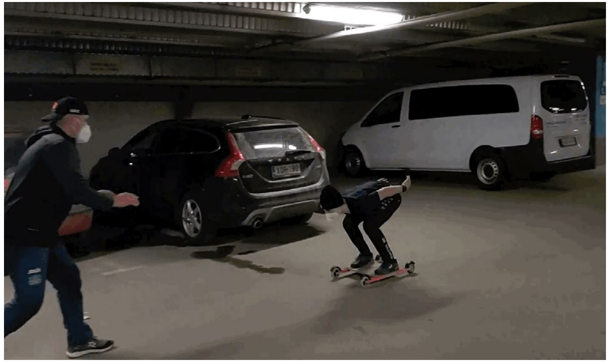
What is Nordic Ski Jumping?

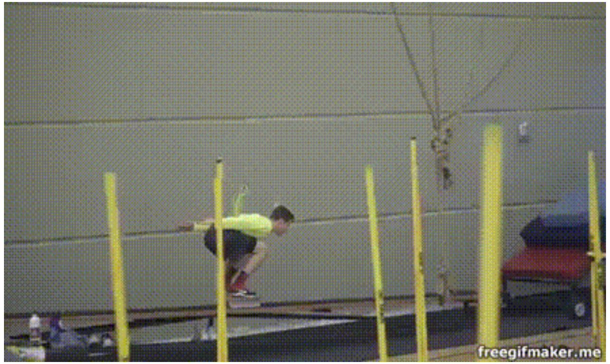
Video Credit: [FIS Ski Jumping]

Project Motivation

- **USA Nordic Ski** needs a better way to train their ski-jump athletes off the slopes
- Current training methods lack **visual aids,** cause the athlete to experience unrealistic **external forces**, and do not provide a way to collect **foot force distribution**

USA Nordic's Current Training Methods:





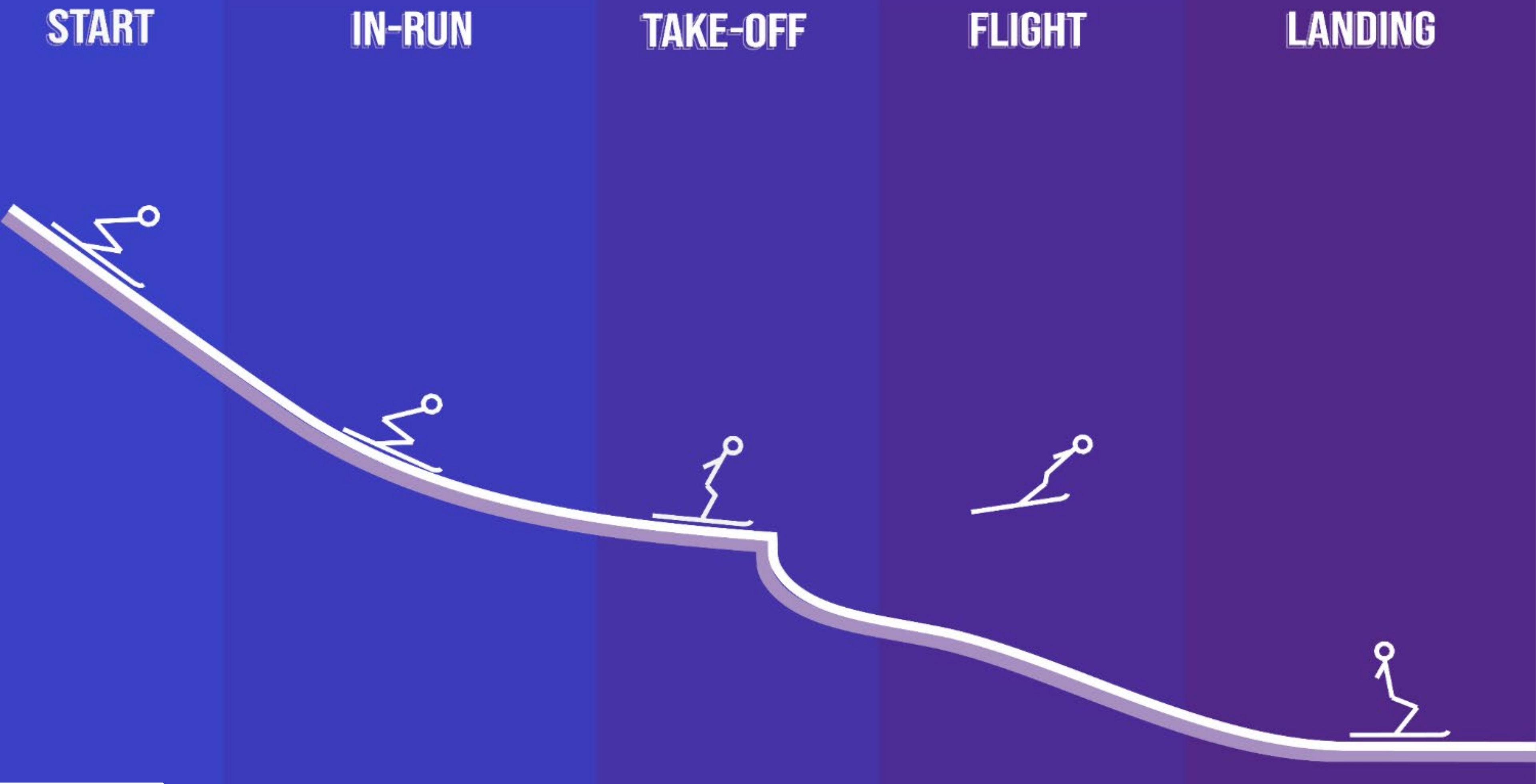
Videos courtesy of USA Nordic

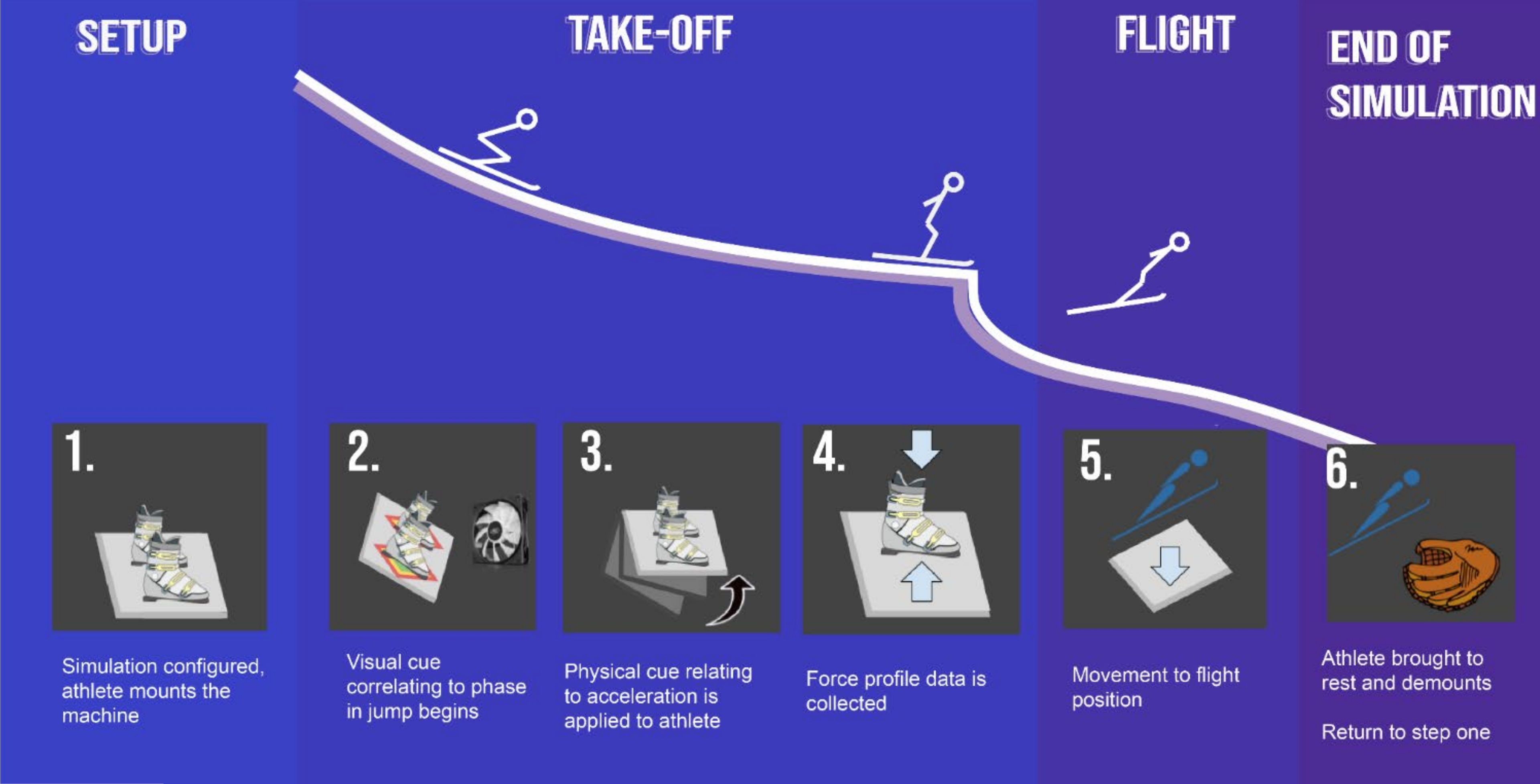
Mission Statement

SKi jump Athletic Development Interface (**SKADI**) will provide the **USA Nordic** team with a modern training device that will **visually** and **physically** model the effects of a ski jump while **measuring the force** applied by the athlete.

Functional Requirements

ID	Functional Requirement
FR1	SKADI shall provide visual cues correlating to the phase in jump.
FR2	SKADI shall provide force and motion cues correlating to the phase in jump.
FR3	SKADI shall be able to support the forces generated when used by the full range of USA Nordic athletes.
FR4	*SKADI shall be able to be disassembled, transported, and reassembled with standard tools and equipment.*
FR5	SKADI shall capture the data of the athlete's force profile.
FR6	*SKADI shall safely bring the user to rest following the jump.*
FR7	*Each use of the SKADI simulation shall require less than 5 minutes.*
FR8	*SKADI shall be operable within a gymnasium while other athletes are adjacently training.*

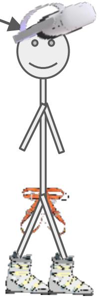

START
IN-RUN
TAKE-OFF
FLIGHT
LANDING


SETUP
TAKE-OFF
FLIGHT
END OF SIMULATION
1.
Simulation configured, athlete mounts the machine
2.
Visual cue correlating to phase in jump begins
3.
Physical cue relating to acceleration is applied to athlete
4.
Force profile data is collected
5.
Movement to flight position
6.
Athlete brought to rest and demounts
Return to step one

Baseline Design: Visual

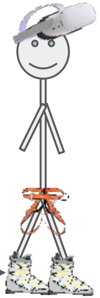
VR Headset:
Oculus Quest 2

User



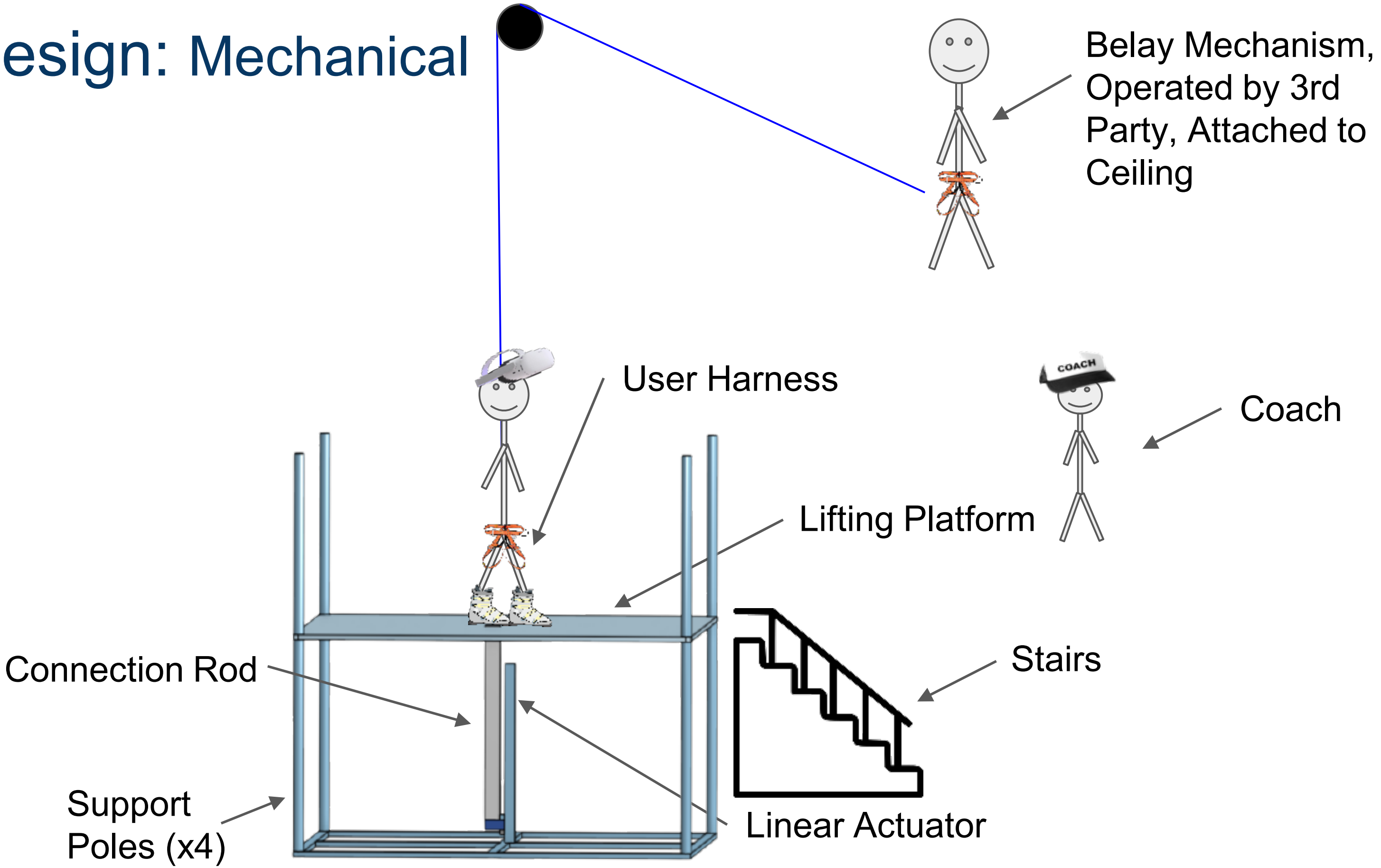
Baseline Design: Force Data Collection

User

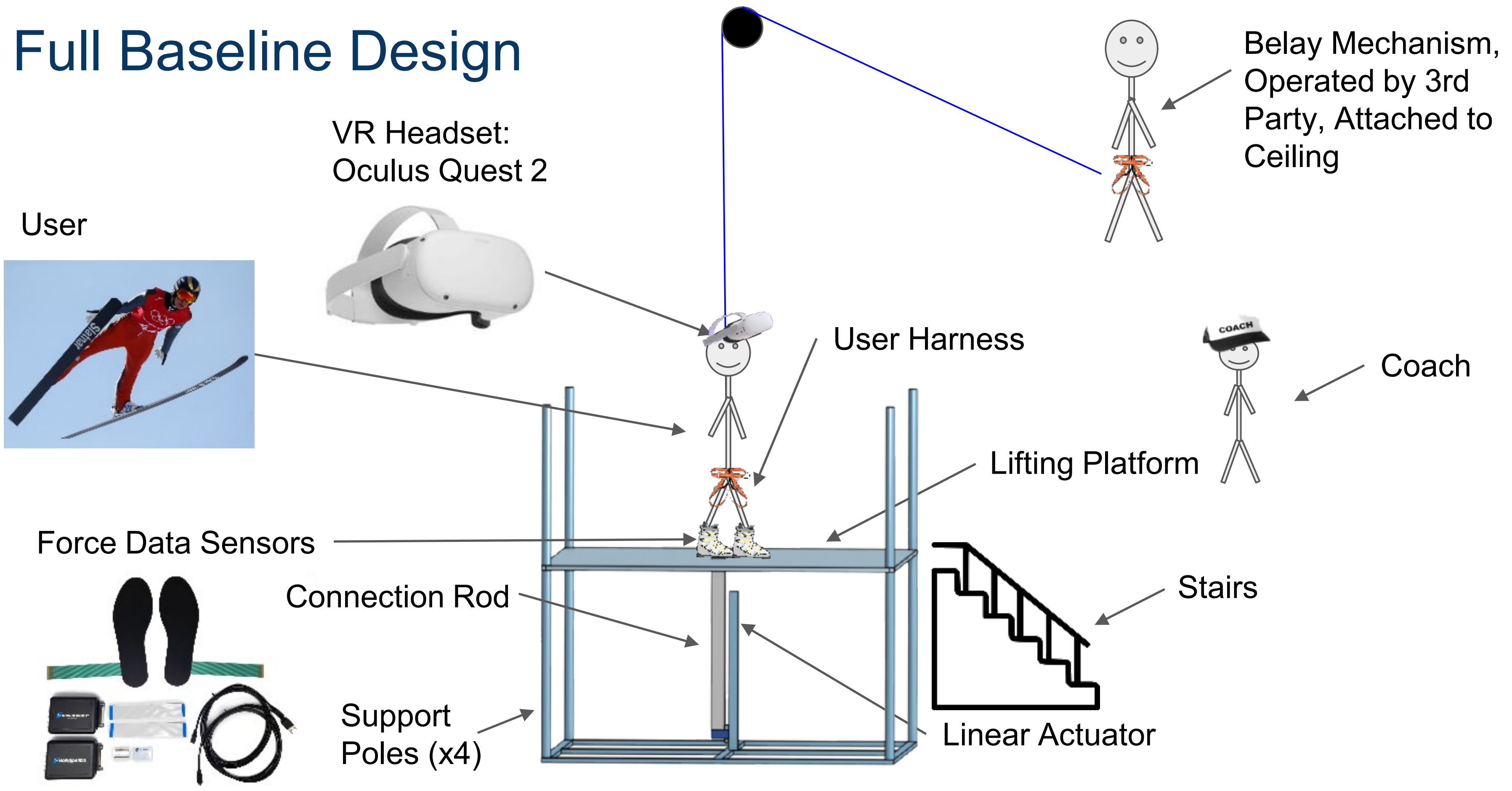


Force Data Sensors

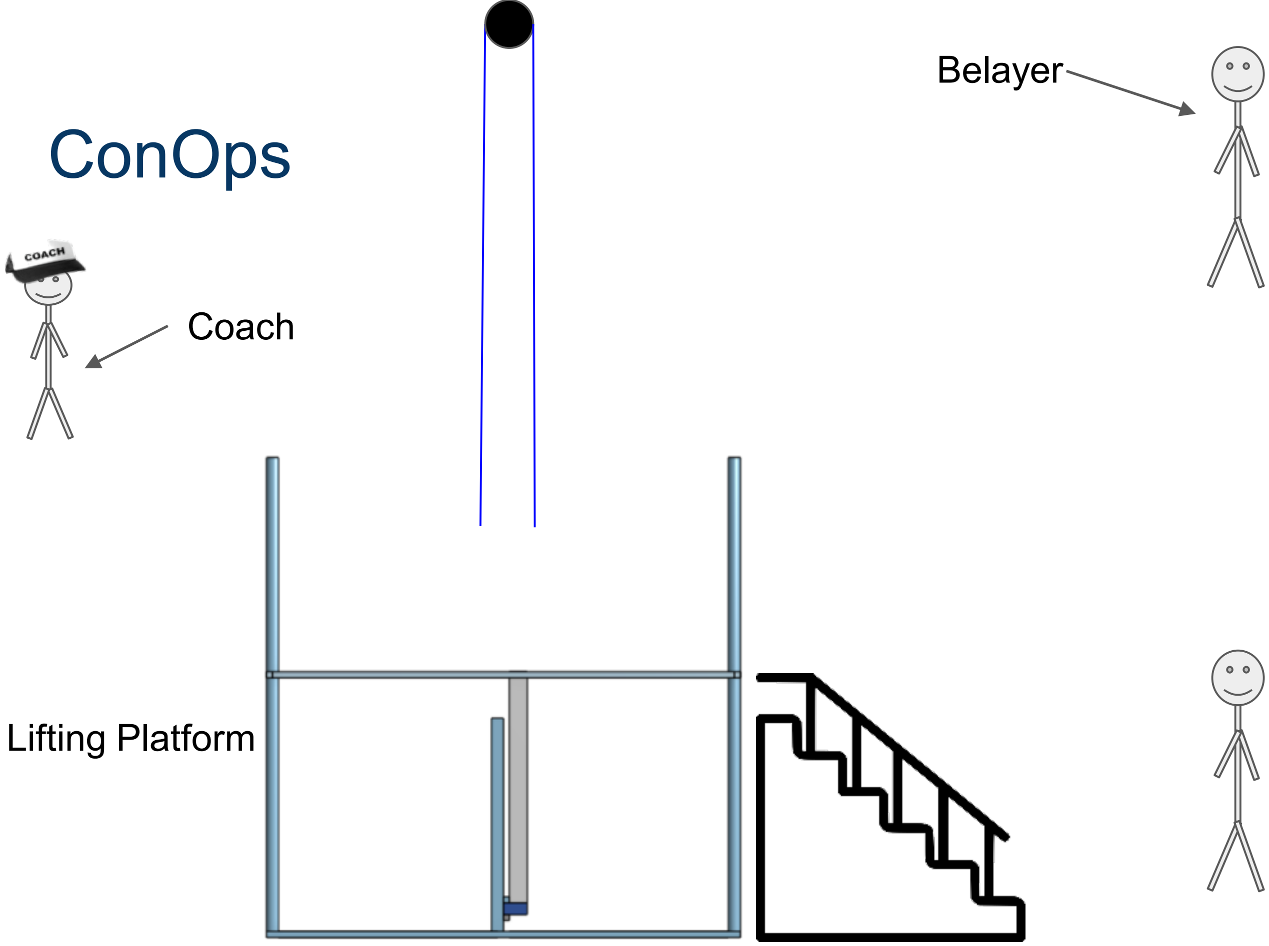
Baseline Design: Mechanical



Full Baseline Design



ConOps

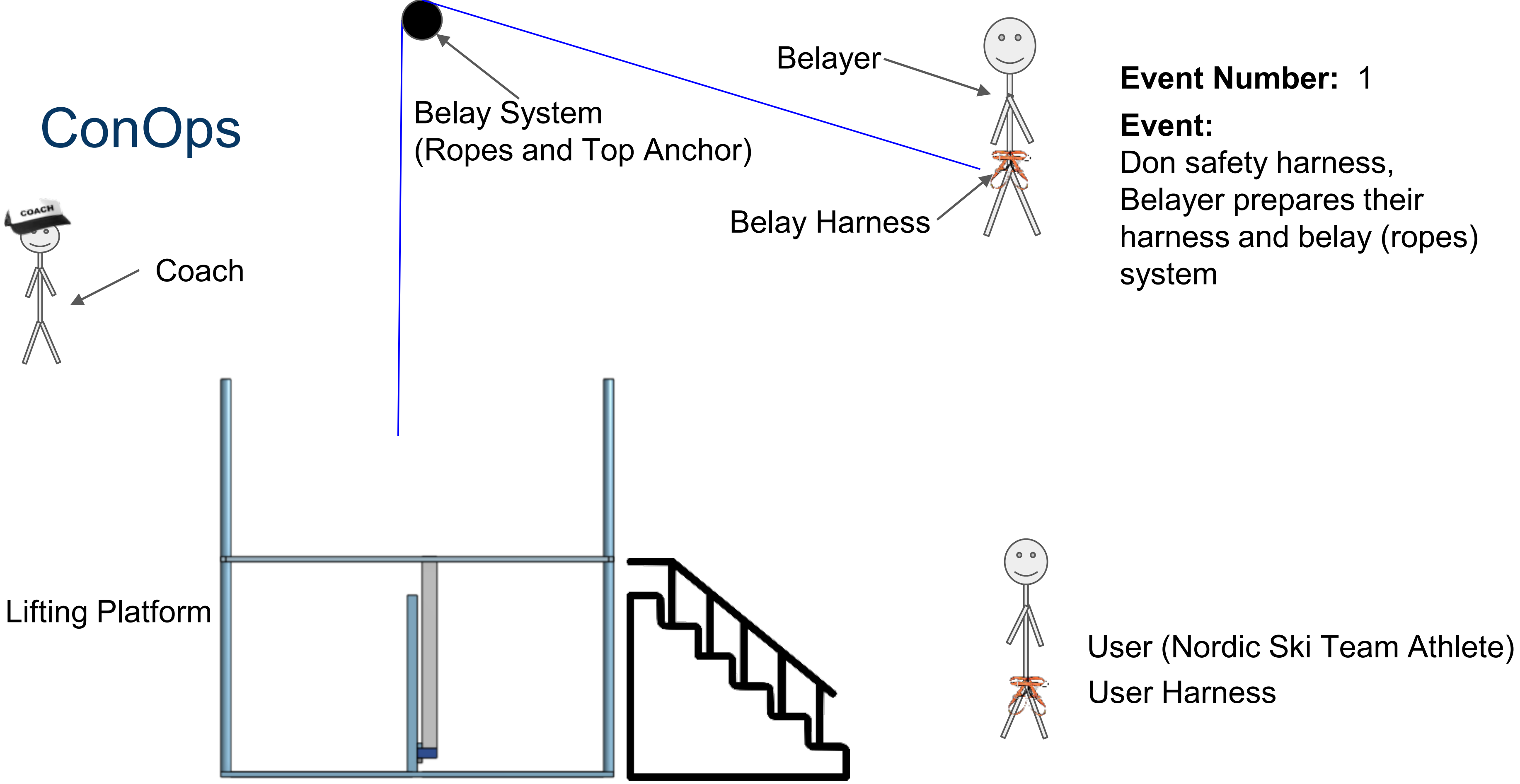


Event Number: 0

Event:
User, Coach, and Belayer enter defined area for SKADI training

User (Nordic Ski Team Athlete)

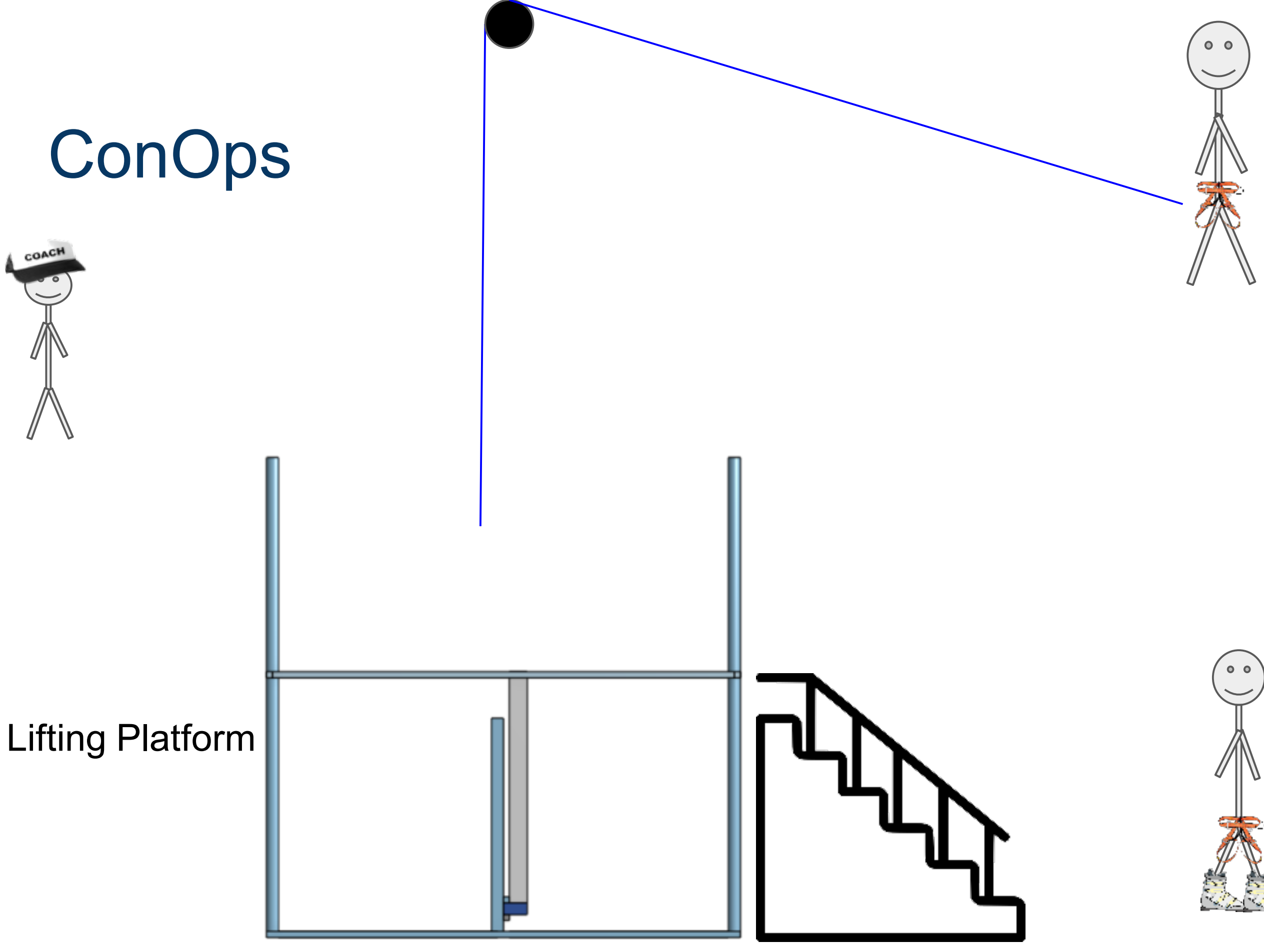
ConOps



Event Number: 1

Event:
Don safety harness, Belayer prepares their harness and belay (ropes) system

ConOps



Event Number: 2

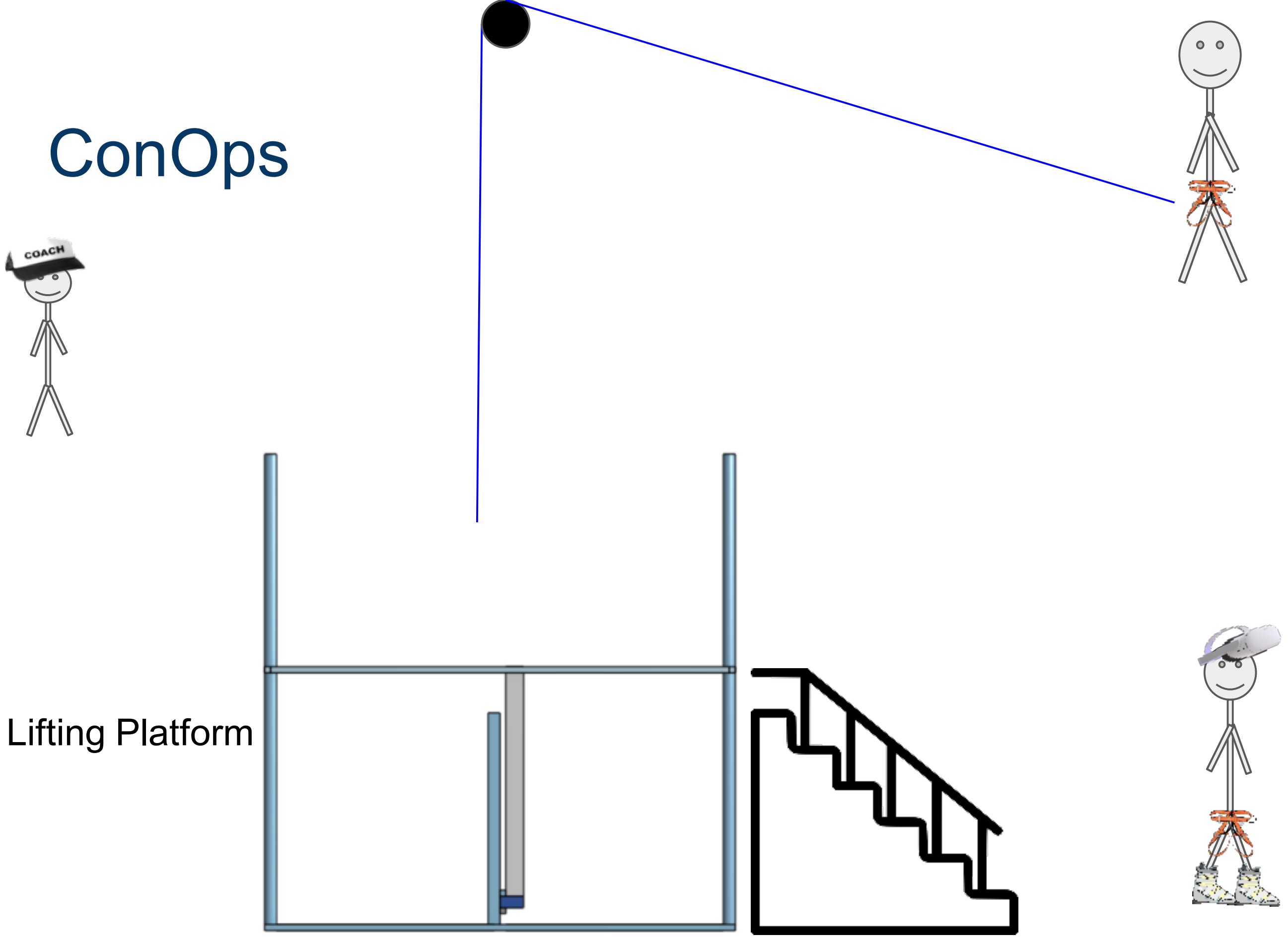
Event:
Don Training Boots
(User's personal boots,
Force Data Insoles inserted)

User (Nordic Ski Team Athlete)

User Harness

Training Ski Boots with Force Data Insoles inserted

ConOps



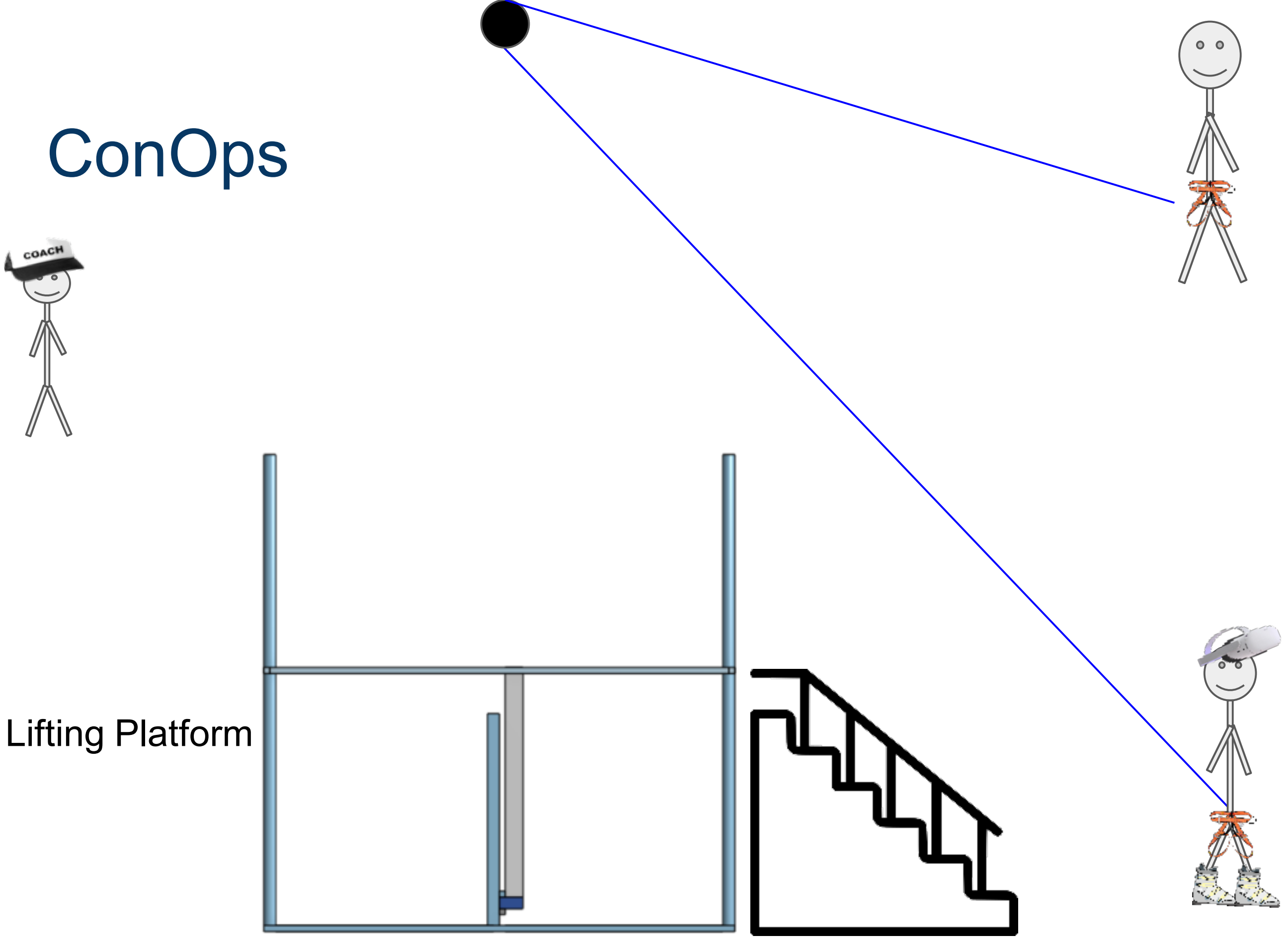
Event Number: 3

Event:
Acquire Standalone VR Headset
(Protected by training helmet)

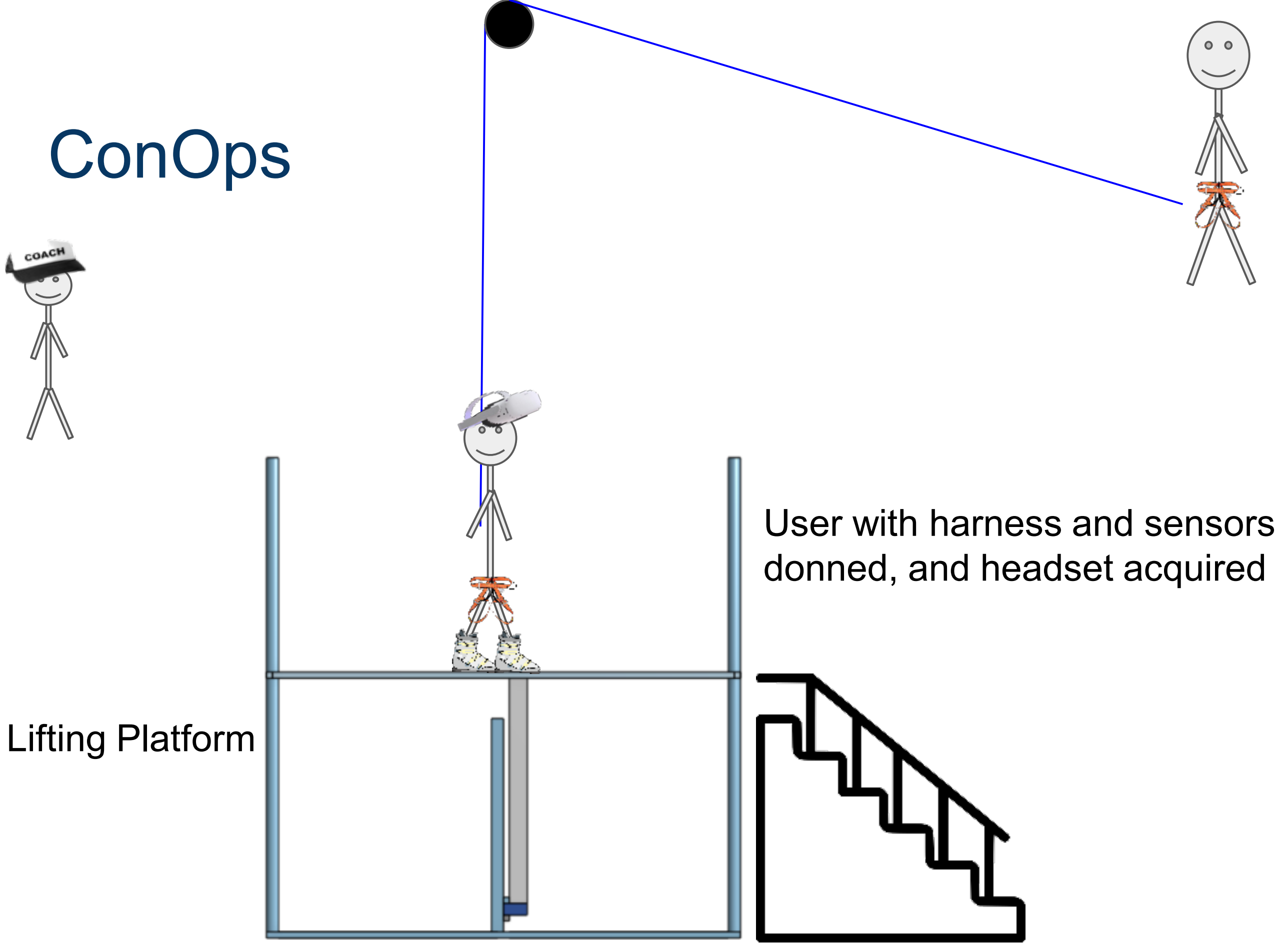
ConOps

Event Number: 4

Event:
Tie into belay mechanism



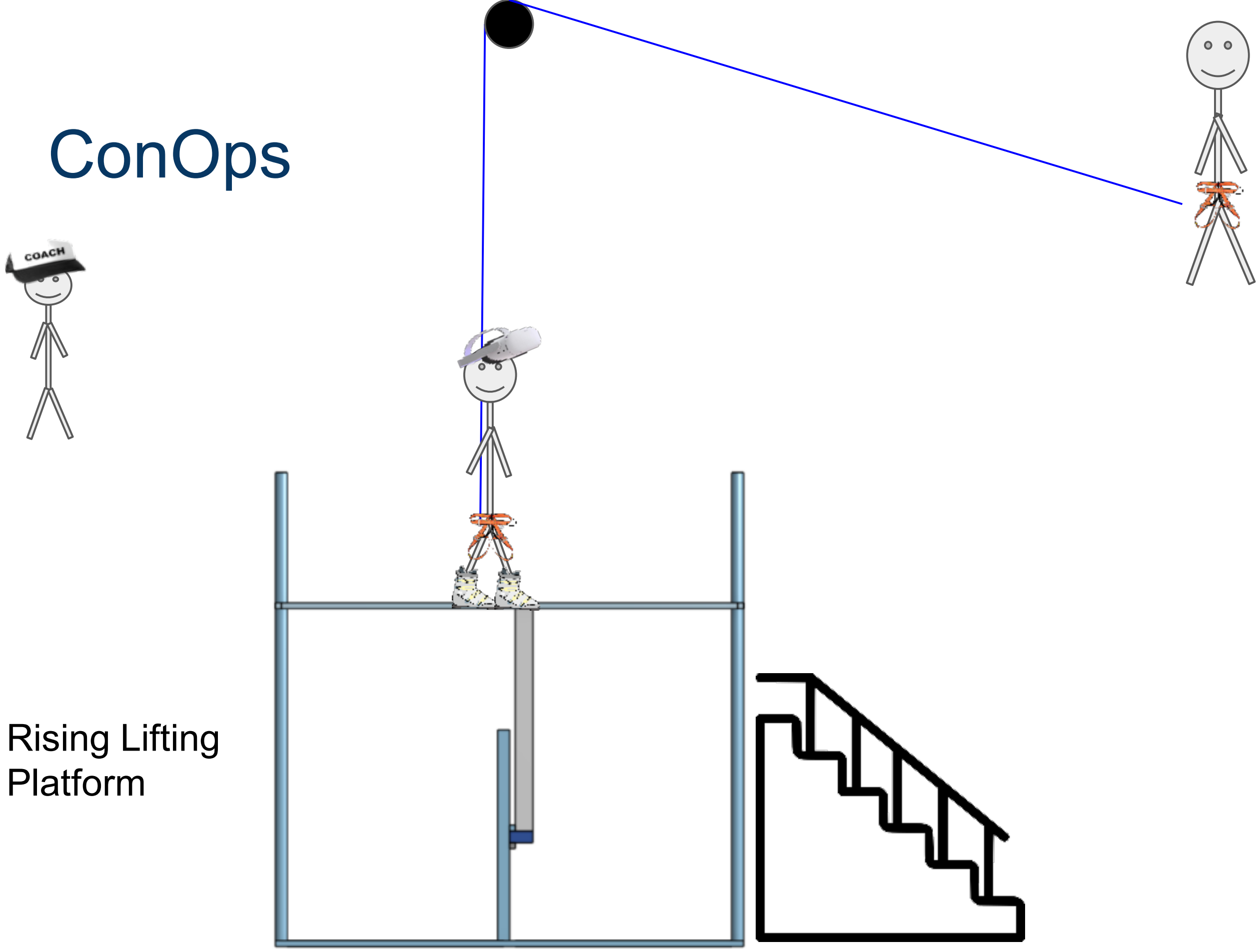
ConOps



Event Number: 5

Event:
Mount Lifting Platform (Currently Lowered)

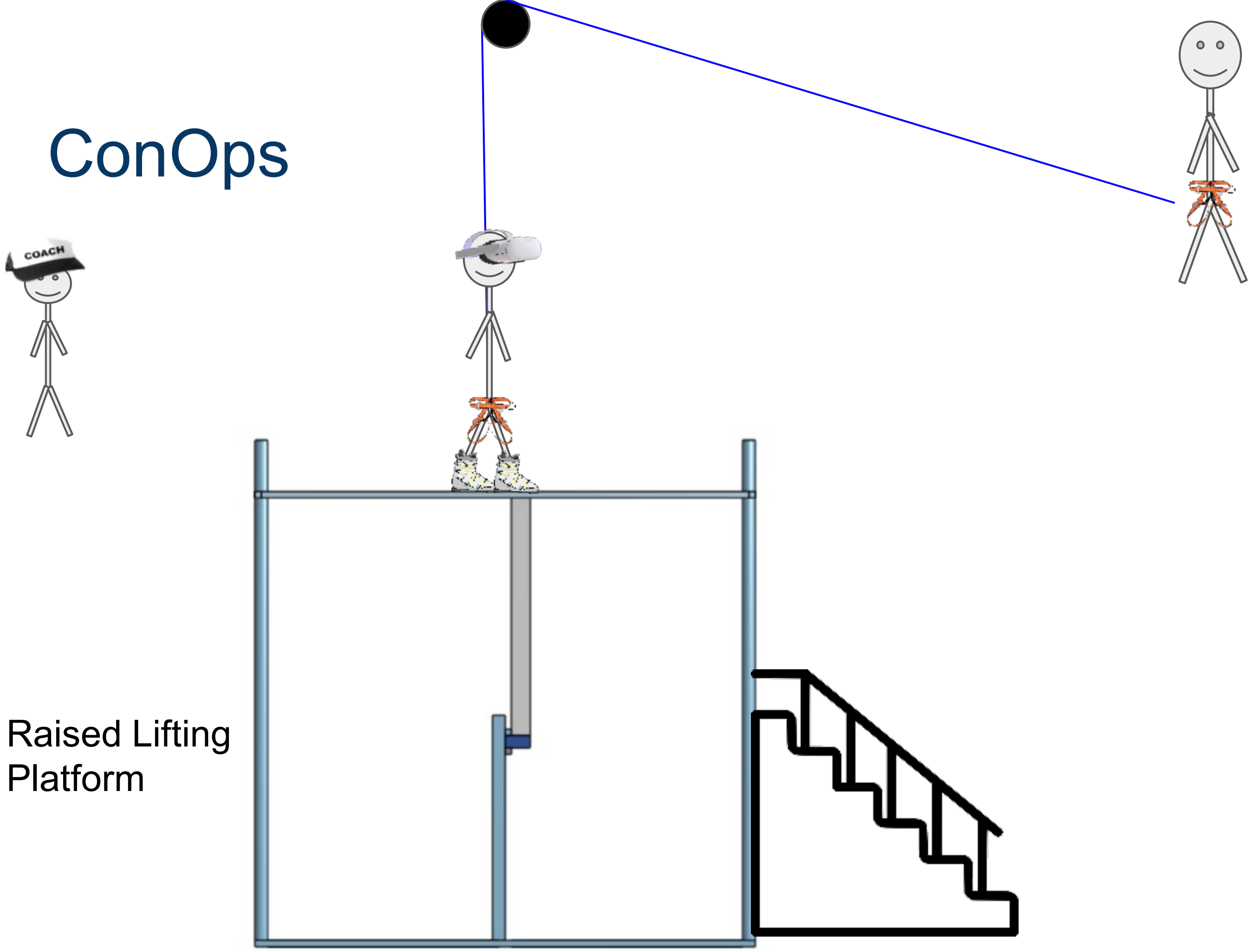
ConOps



Event Number: 6

Event:
Lifting Platform rises slowly

ConOps

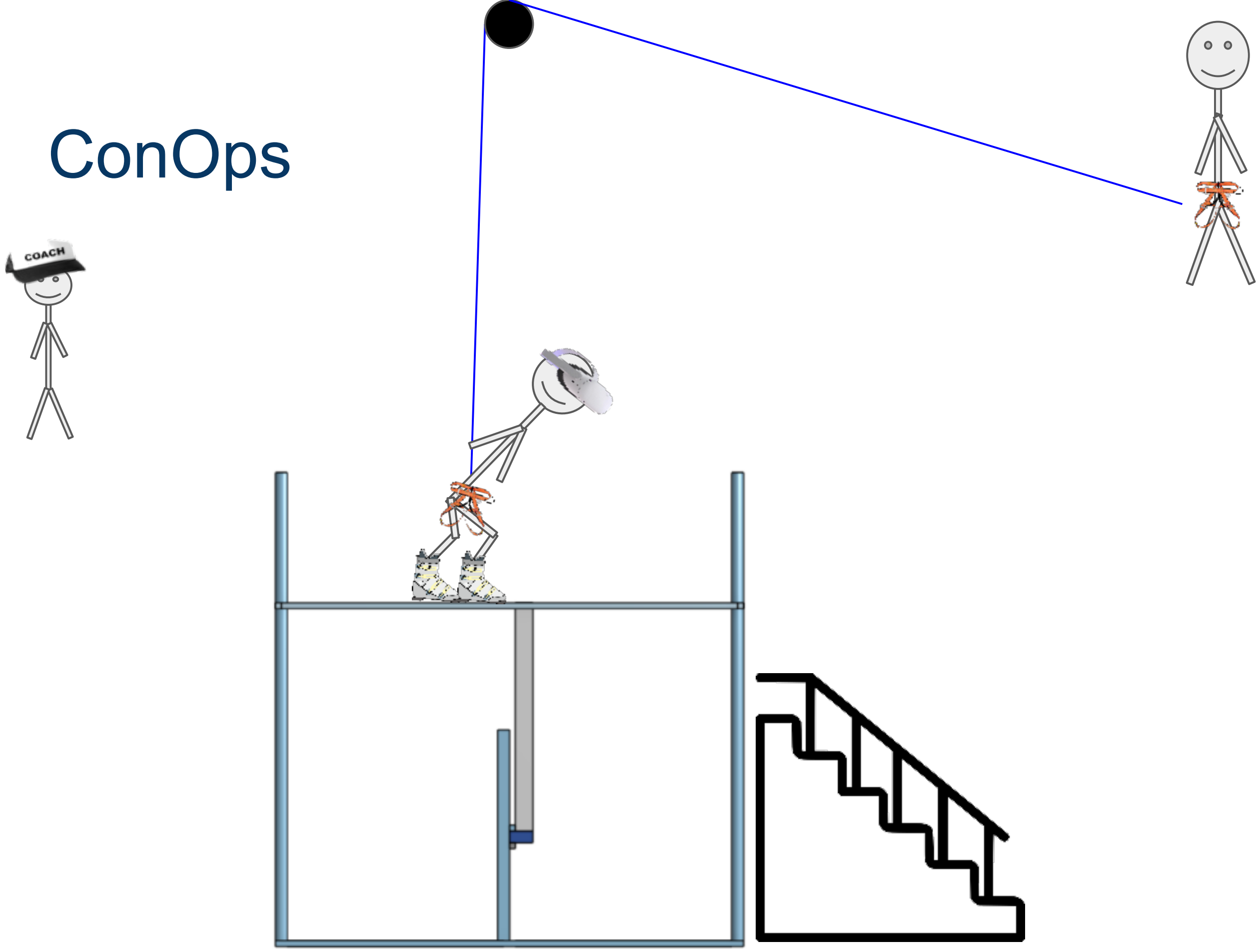


Raised Lifting Platform

Event Number: 7

Event:
Don standalone VR Headset.
Begin VR Simulation.
Begin force data collection.

ConOps

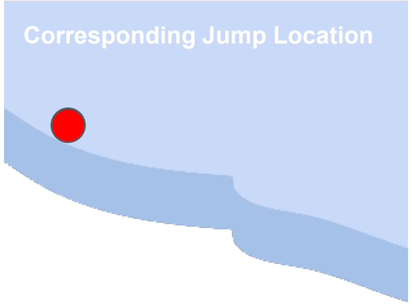


Event Number: 8

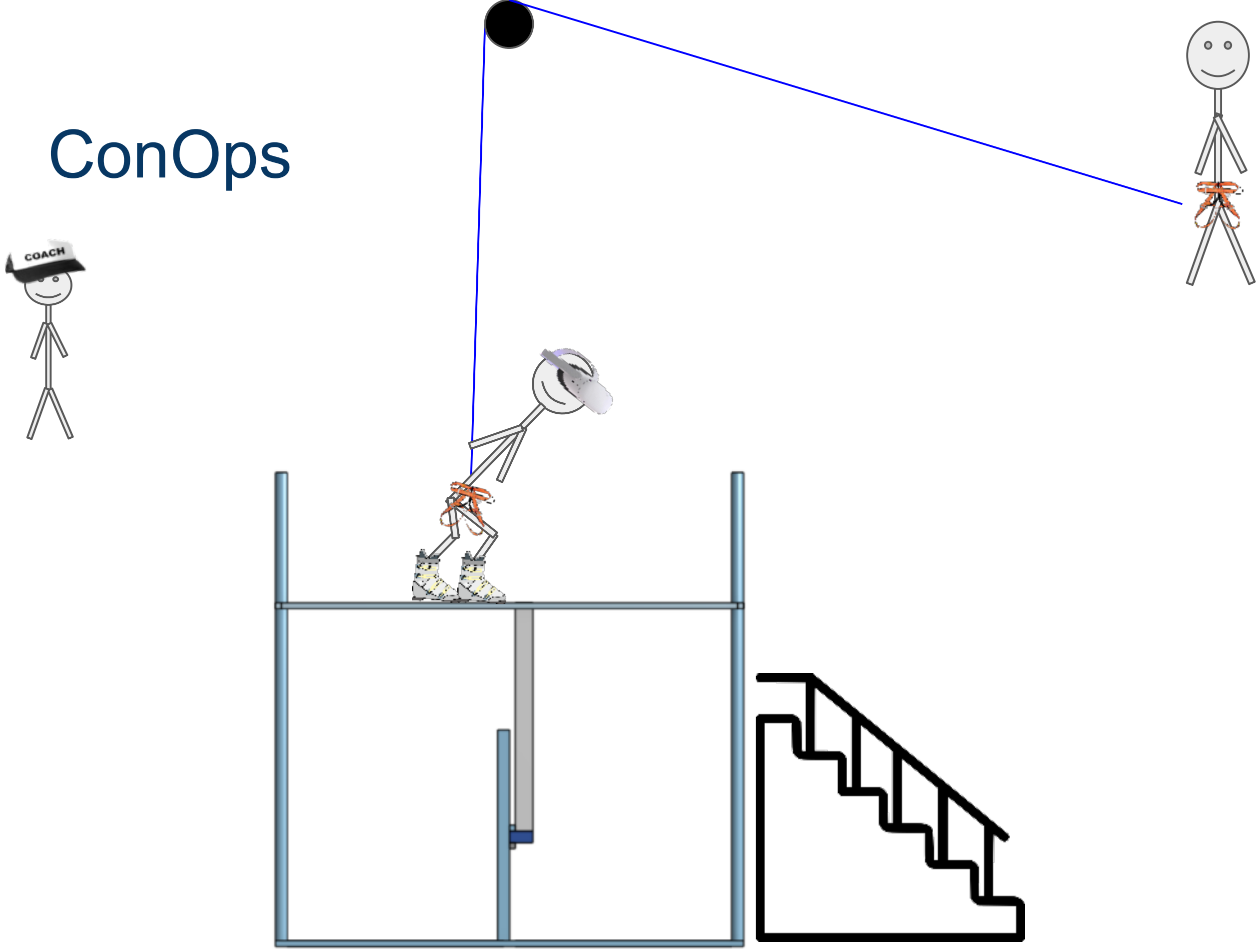
Event:
Lifting Platform drops quickly, allowing User to reach downward velocity of 0.64 [m/s]

VR Simulation mimics motion on ski jump ramp

Force data is continuously collected



ConOps

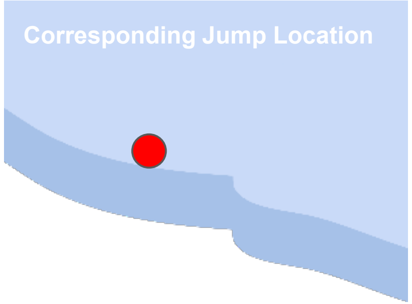


Event Number: 8.1

Event:
Lifting Platform, moving downward, begins upward acceleration (causing upward normal force on user, creating sensation of compression)

VR Simulation mimics motion on ski jump ramp

Force data is continuously collected



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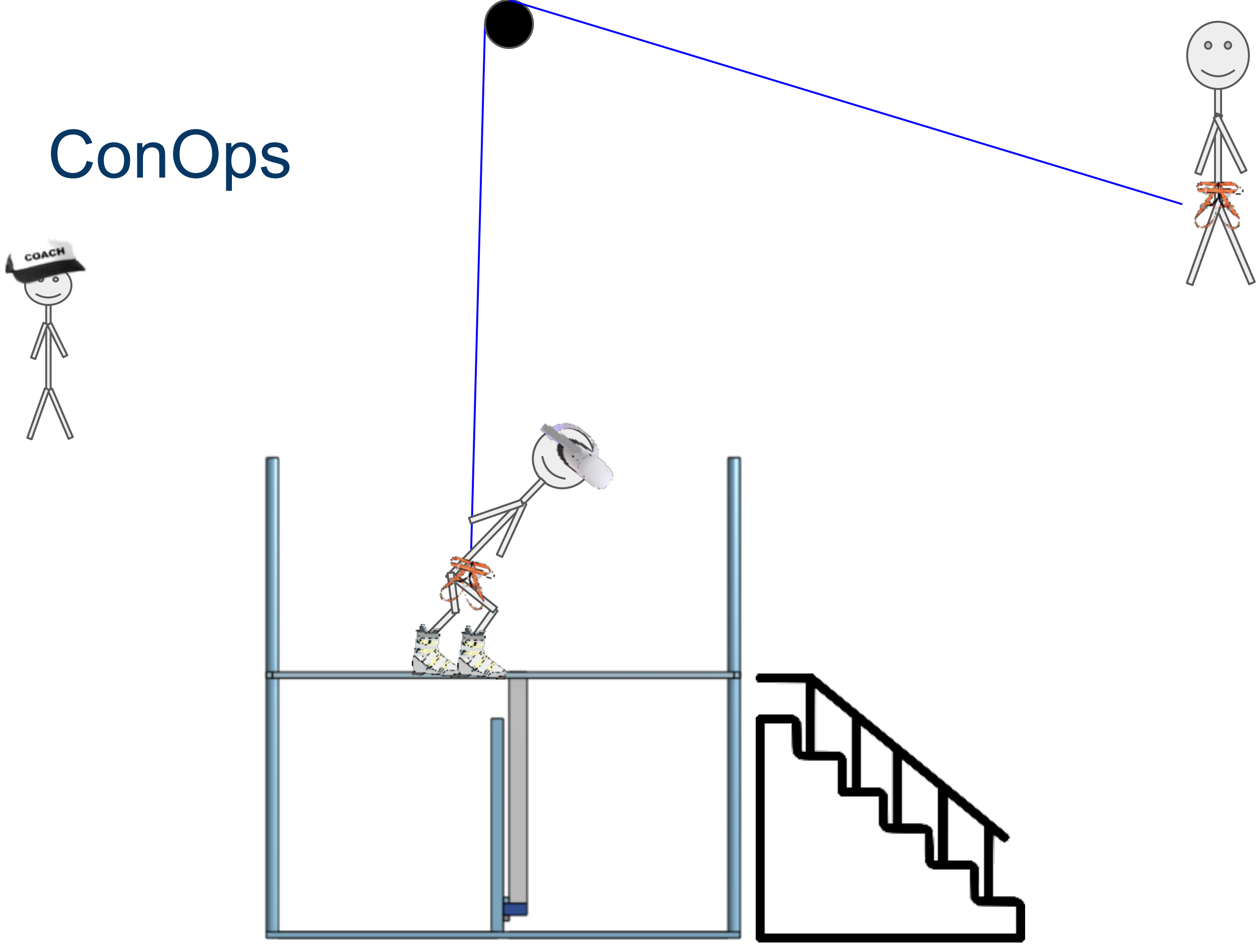
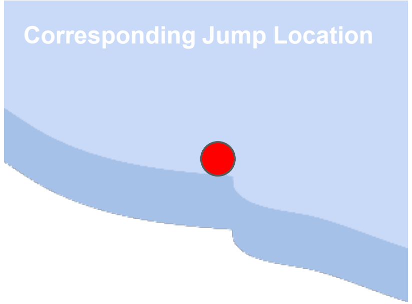


Event Number: 8.2

Event:
Lifting Platform, having become motionless, now has upward velocity - continuing upward acceleration (User continues to experience compressive force)

VR Simulation approaches end of ski jump ramp

Force data is continuously collected



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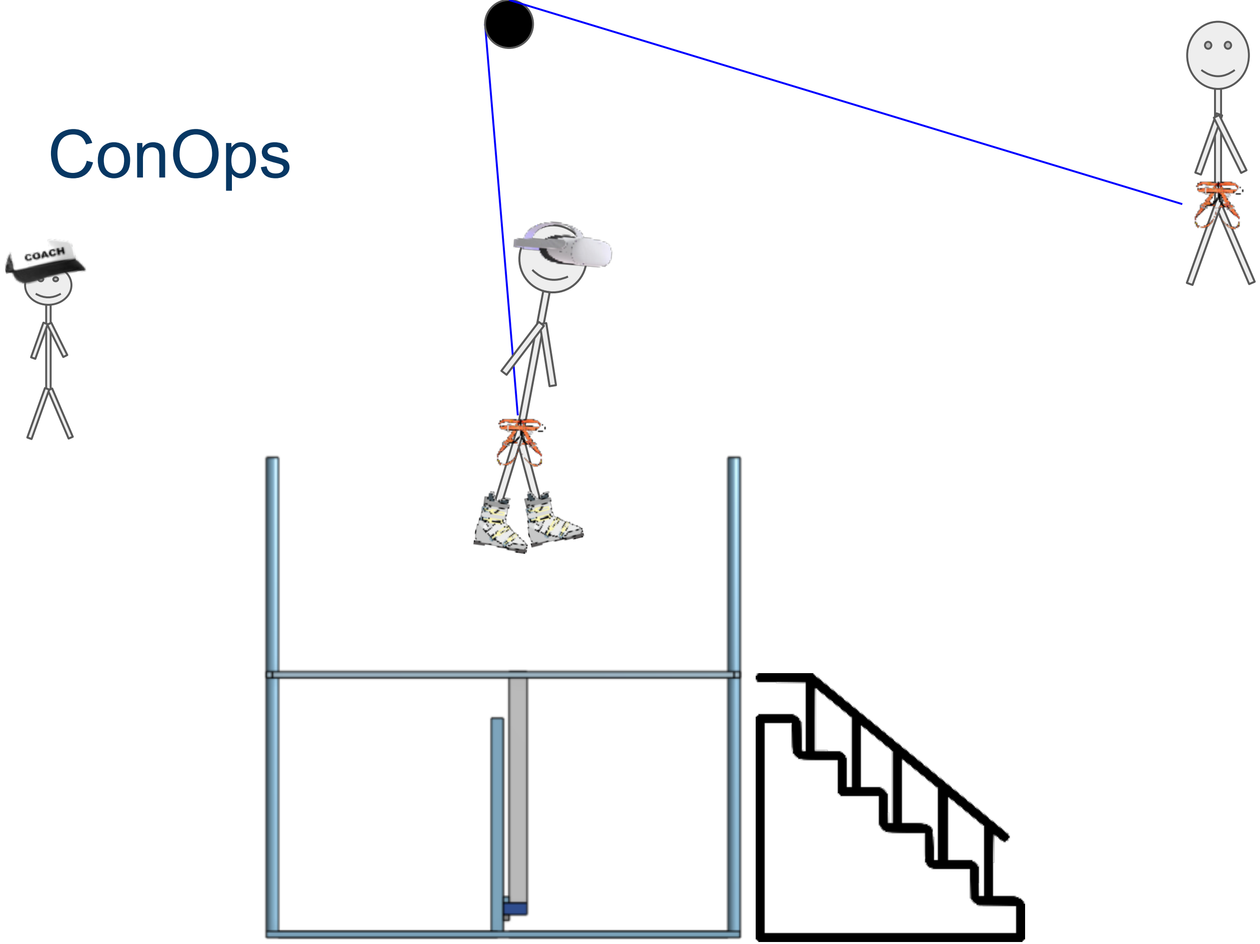
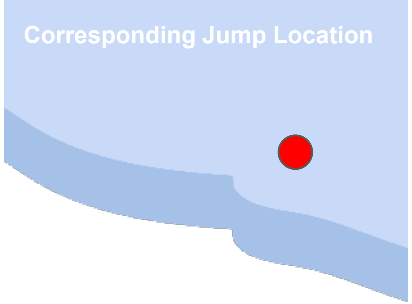


Event Number: 9

Event:
VR Simulation indicates end of ski jump ramp

User jumps from lifting platform

Force data is continuously collected



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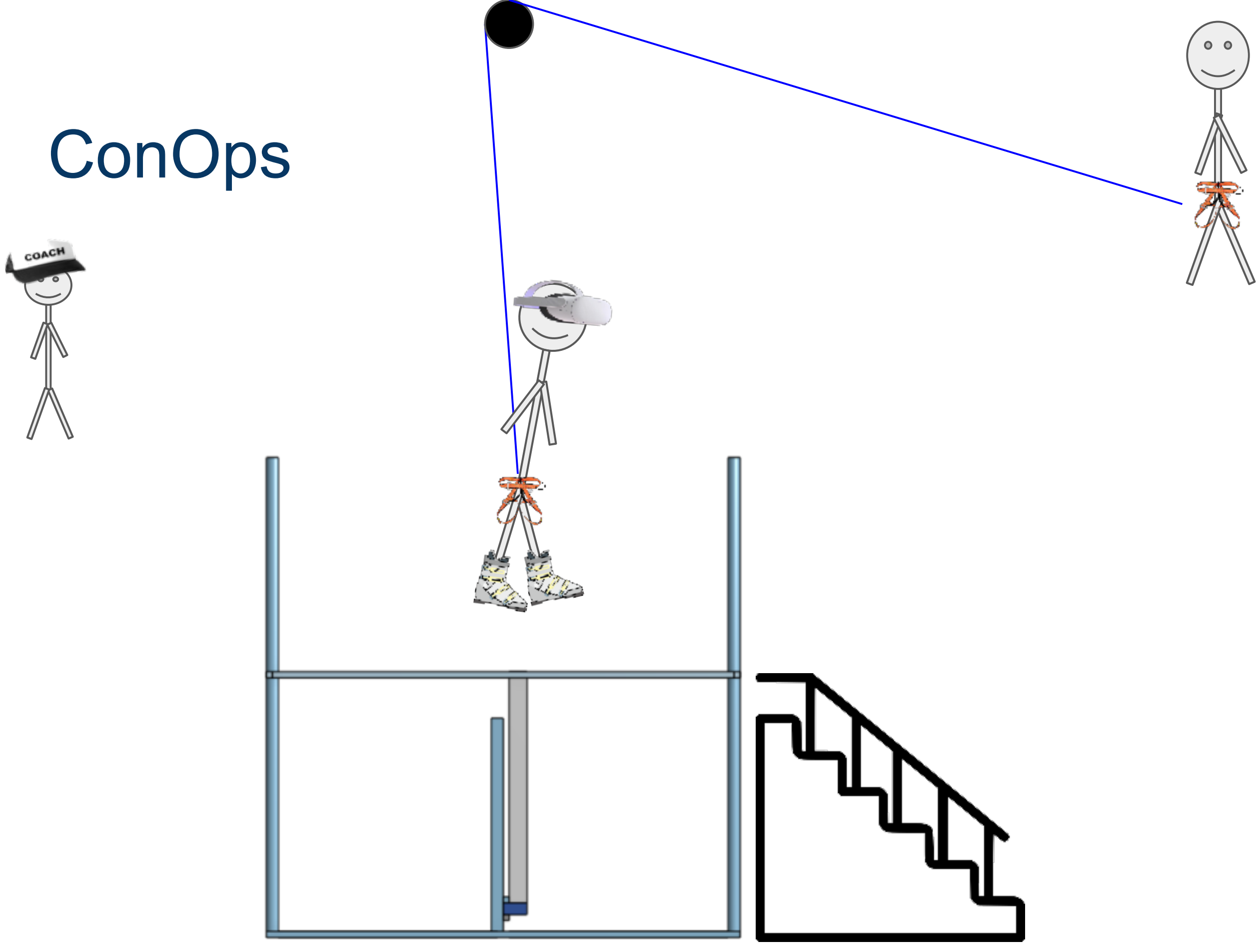


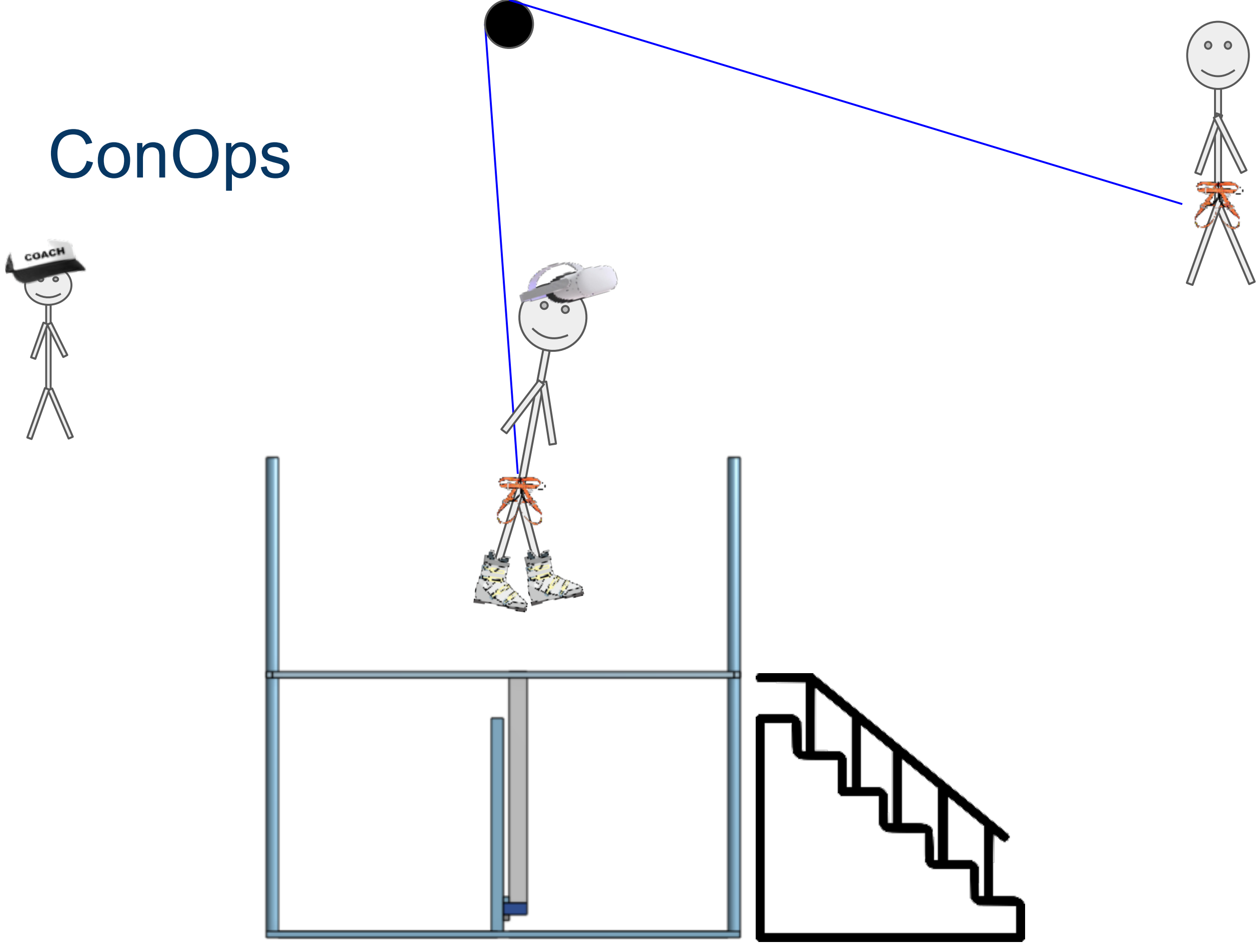
Event Number: 10

Event:
VR simulation turns off

Data collection ceases

User is caught by belayer with belay system

ConOps

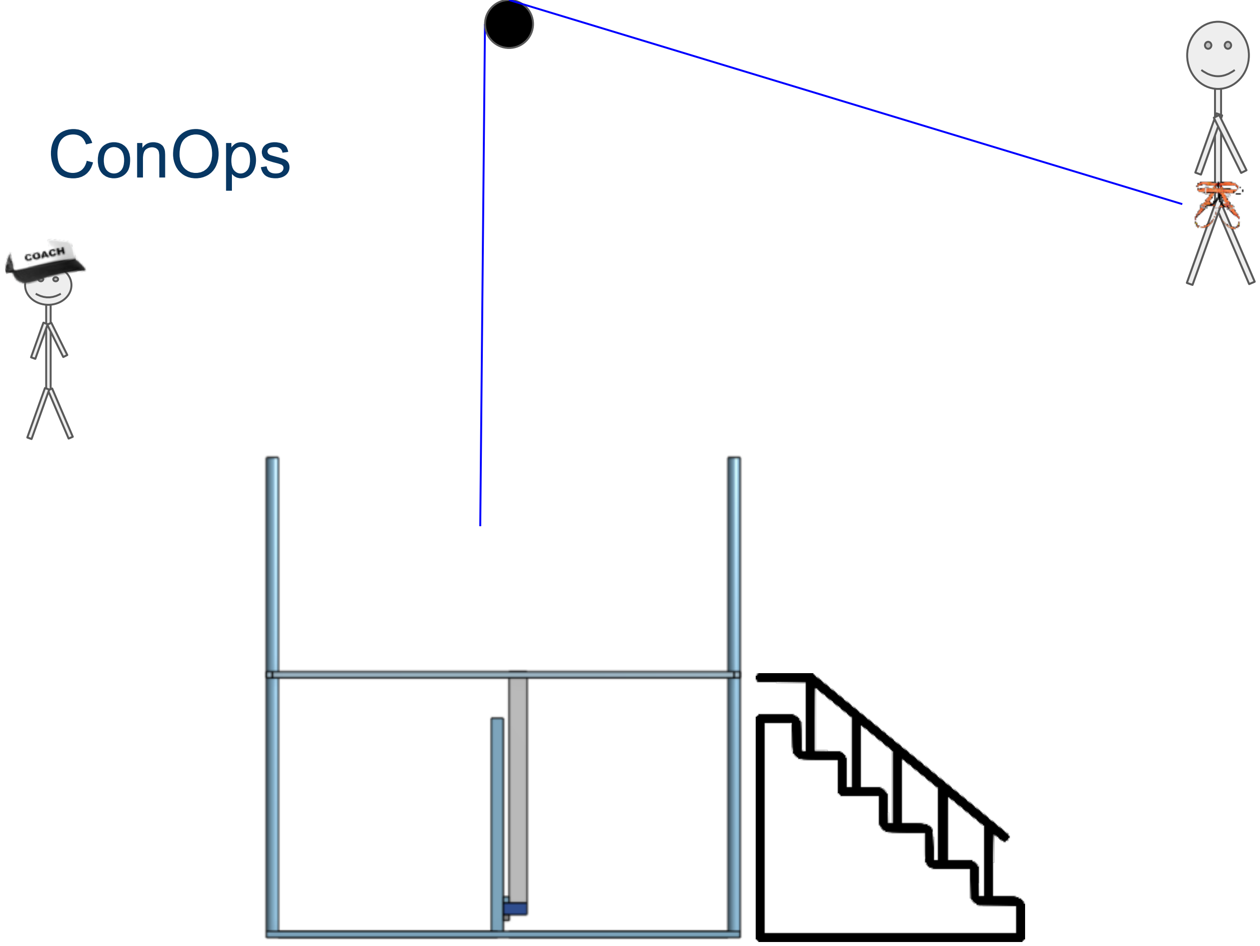


Event Number: 11

Event:
User removes VR Headset

User is lowered to platform by belay system

ConOps

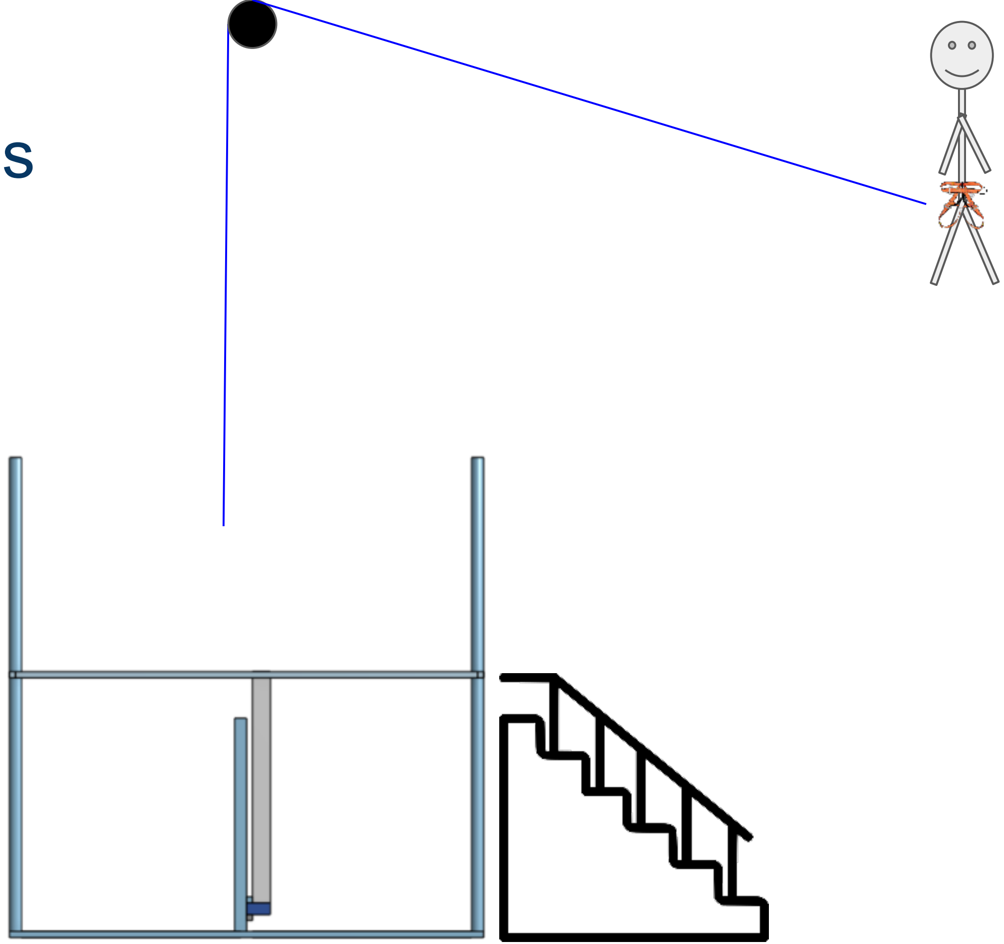


Event Number: 12

Event:
User detaches from belay device

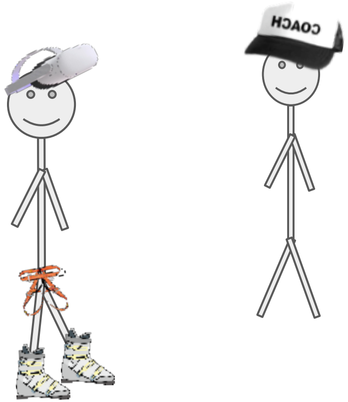
User demounts lifting platform, optionally doffs headset and boots

ConOps

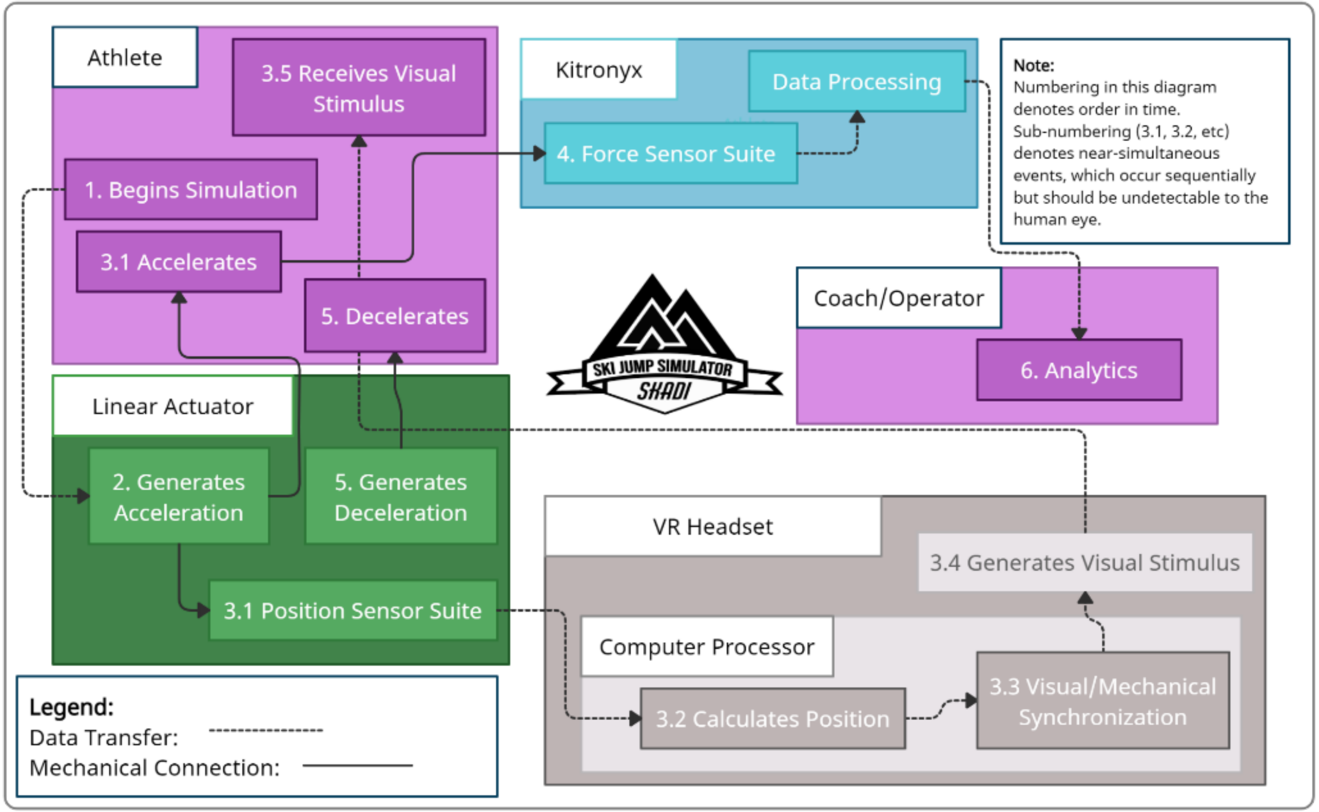


Event Number: 13

Event:
Coach and user analyze force data, discuss improvements. Training simulation may be repeated.



Functional Block Diagram



(Evidence of Baseline Feasibility)

Critical Elements

Presenters: Mary Sobernheim, Joaquin Ramirez

Section Outline

- Identification of CPEs
- Key Feasibility Elements

Identification of Critical Project Elements (CPEs)

Func. Req.	CPE	Description
FR1	E1	The synchronization of the visual and mechanical subsystems
FR2	E2	The production of similar forces to those experienced by an athlete during ski jump takeoff while supporting at least 200 kg
FR3	E3	The ability of SKADI's users to participate in multiple simulations
FR5	E4	The capturing of user's foot force profile throughout the takeoff phase

Key Feasibility Elements

Label	Functional Requirement	CPE	Description
VIS	FR1	E1	Headset that is able to display visual cues and be synced with physical cues
MECH	FR2	E2,E3	Linear actuators that provide analogous physical cues to that of an Olympic ski jump Supports weight of athlete with FOS of (#)
FOOT	FR2, FR5	E4	Pressure mapping system that successfully records necessary data throughout the simulation Supports weight of athlete with a FOS of 1.1
COST	Budget	Budget	The total monetary cost of SKADI must be <$5k.

(Evidence of Baseline Feasibility)

Feasibility Analyses

Presenters: Michael Schlittenhart, Landon Nurge, Julia Sheeran

Section Outline

- Visual Feasibility (VIS)
- Mechanical Feasibility (MECH)
- Force Data Collection Feasibility (FOOT)
- Financial Feasibility (COST)

Visual Feasibility (VIS)

Visual Feasibility Analysis Justification

1) 2)

"FR1: SKADI shall provide visual cues correlating to the phase in jump."

1) **Display visual cues** - use Oculus Quest 2

2) **Synchronize visual cues with physical stimuli** - synchronize VR presentation with physical platform motion

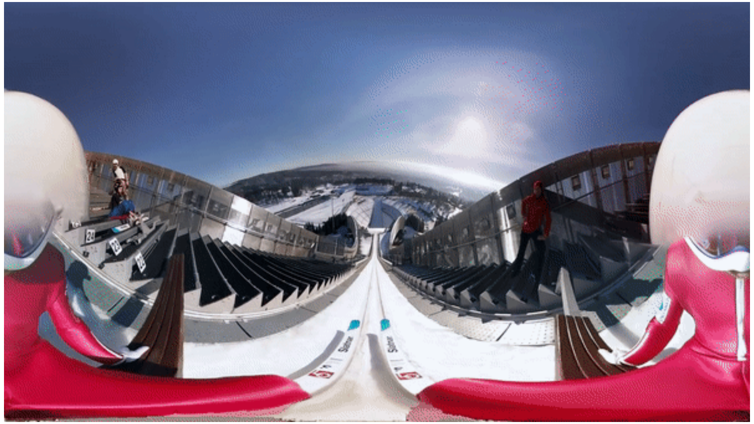
Visual Feasibility Analysis - Display Format

Display Format Options:

1) Animated Video Game

[1] Ski Jump VR Game Trailer, 2017

2) 180° or 360° Video



[2] NRK Sport, 2017

Visual Feasibility Analysis - Display Format

Display Format	**Animated Video Game**	**180° or 360° Video**
Fulfills Requirement?	Yes	Yes
Functional with Oculus Quest 2?	Yes (via Unity [3])	Yes (via apps from Oculus App Store [4])
Demonstration of Functionality	[5] Demonstrates integrating Unity project into Oculus Quest 2	[6] Describes how to export video into Oculus Quest 2. [7] Demonstrates uploading and viewing video on Oculus Quest 2
Feasible?	**Yes**	**Yes**

Visual Feasibility Analysis - Timing

Timing with Physical Cues Options:

1) Manual Start
   - Manually begin VR Simulation from Goggles
   - Less precisely synchronized with physical system
   - Less development work required

1) Software Integration
   - Integrate VR start with start of physical system using software
   - Unsure if VR can be started with external software
     - Awaiting reply from Oculus
   - Better synchronized with physical system

Visual Feasibility Analysis - Timing

Timing	Manual Start	Software Integration
Fulfills Requirement?	Yes	Yes
Description of Functionality	User would manually begin visual simulation on VR headset. SKADI would have timing worked out with instructions on how to align that with physical cues	SKADI would connect the software to start the physical and visual simulations simultaneously
Feasible?	**Yes**	**TBD***

*Will pursue if feasible

VIS Feasibility Analysis Results

Requirement	Design that Fulfills Requirement	Feasible?
Display Visual Cues	Animated video game/ recorded video	Yes
Synchronize visual cues with physical stimuli	Manual Timing	Yes

Visual Feasibility: Yes

Mechanical Feasibility (MECH)

Driving Requirements

“FR2: SKADI shall provide force and motion cues correlating to the phase in jump”

- SKADI will cue the beginning of the transition to flight phase by enacting analogous forces on the ski jumper.
    - The platform must exert a compressive force of at least +0.06 *Gs* on the athlete
    - The total displacement shall be minimized for the sake of volume constraints
- The mechanical system will minimize forces that are not felt during an actual jump to preserve immersion

“FR3: SKADI shall be able to support the forces generated when used by the full range of USA Nordic athletes”

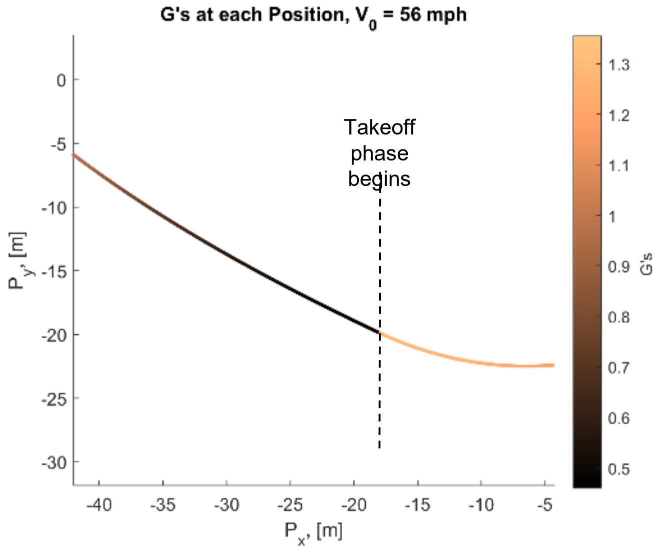
- The velocity shall be minimized for the sake of user safety

Assumptions

- Maximum 200 kg needs to be supported by the mechanical system
  - According to the 2014 Sochi Olympics database, winter athlete weights vary from 53kg (lightest female) to 98kg (heaviest male skier).
  - Account for up to 220 kg under maximum Gs
  - Account for up to 50 kg lifting platform
  - Design for 540 kg to ensure FOS of 2
- +0.02 *Gs* = minimum deviation in vertical acceleration that a human can detect [10]
- Kinematic calculations (assuming constant acceleration) can be used to break into the design loop
  - End states calculated numerically using the acceleration profile closely resemble ends states calculated kinematically using the average acceleration across the profile
  - Must still model numerically to ensure constraints are met

Physical Cue

- Transition from in-line to takeoff phase will be simulated mechanically
  - Compressive forces are high during takeoff phase
  - In-line phase does have significant compressive force
- A compressive force will be applied to cue the beginning of the takeoff phase
  - +.02 Gs is the minimum a human can detect
  - +.06 Gs is enough to be felt by the athlete (FOS = 3.0)



G's felt by athlete during in-line and takeoff phase (entered takeoff phase at 56 mph)

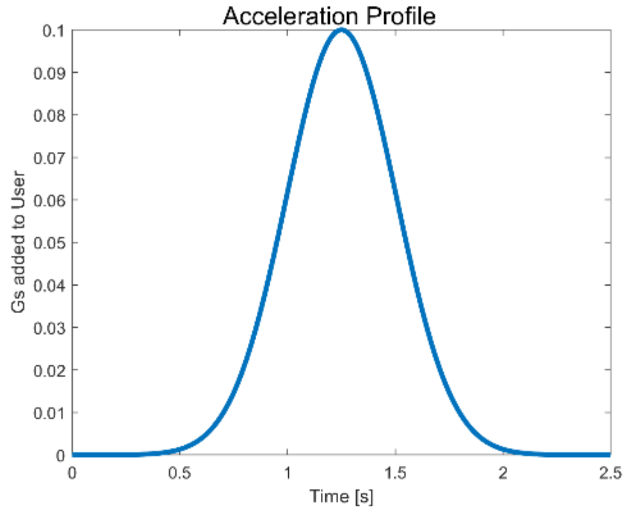
Model: Governing Equations

- Compression Profile
  - Using kinematics, assuming constant acceleration
  - Conditions
    - Simulation Time = 2.5s
    - Displacement = 1m
    - Minimize velocity
    - Maximize acceleration
  - Yield
    - Avg: 0.033 Gs
    - Max: 0.8 m/s

Governing Equation	This Case	Result
$d = \frac{v + v_0}{2} t$	$(1m) = \frac{(0m/s) + v_0}{2}(2.5s)$	$v_0 = 0.8m/s$
$v = v_0 + at$	$0 = (0.8m/s) + a(2.5s)$	$a = 0.033Gs$
$\sigma^2 = \sum \frac{(a-\mu)^2}{N}$	$\mu = 0.033G \quad N = 1000$	*Model*
$a(t) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^2}$	$\mu = 0.033G \quad \sigma = STDEV$	*Model*

Enacting a Compressive Force

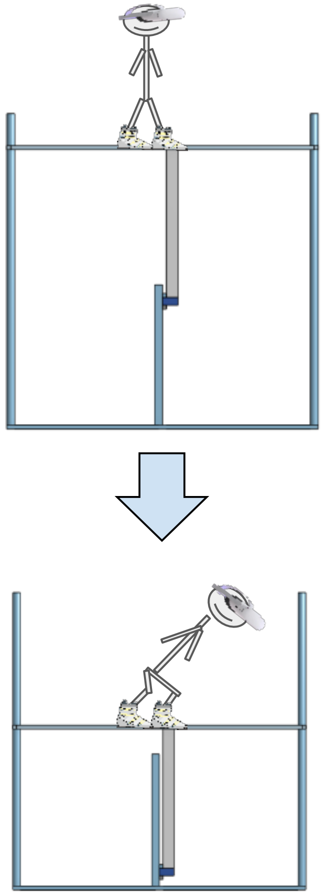
- Forces cannot be enacted immediately
  - Need a gradual application of acceleration
- This Gaussian curve describes how the compression will be enacted
- Driving Constraints:
  - (Time of simulation) Time = 2.5s
  - (Volume) Vertical displacement is to be < 1m
  - (Safety) Velocity is to be minimized
  - (Gs) User is to experience at least +0.06 Gs



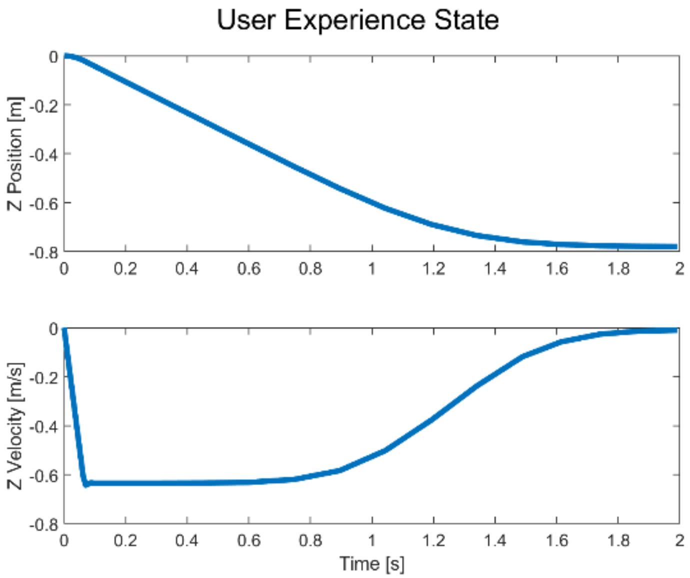
Gaussian profile to apply Gs to athlete

Enacting a Compressive Force

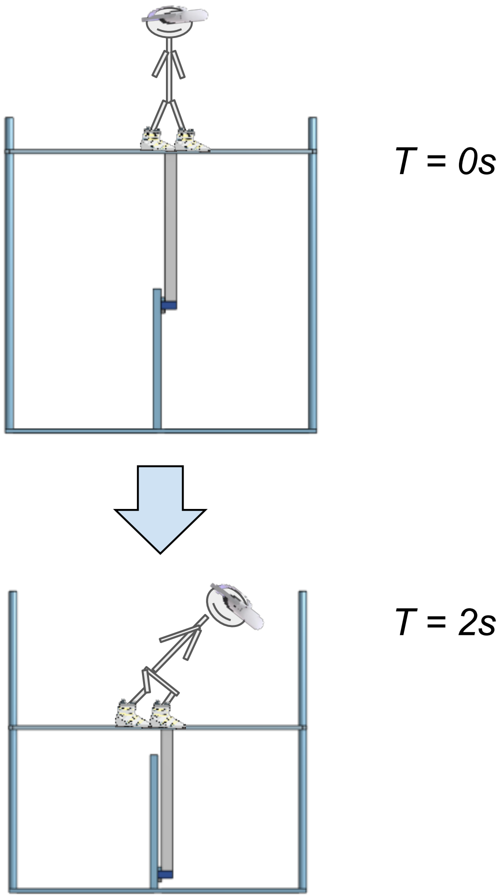
- Start with free fall to generate velocity
- Accelerate upward to generate compression
- Bring athlete to rest
- User states
  - ode45 integration
    - Acceleration = 0 until necessary speed is reached
    - Acceleration follows Gaussian curve



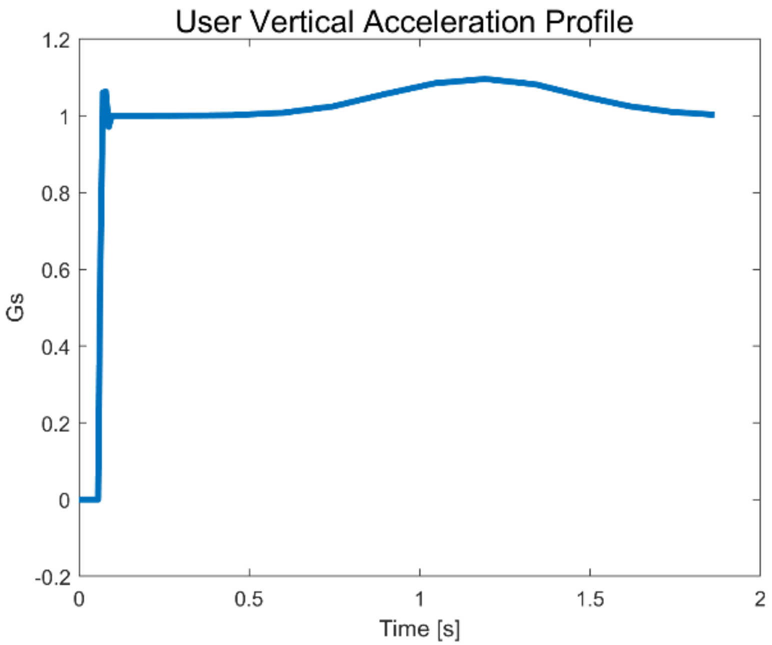
Enacting a Compressive Force



Position and velocity state of user throughout simulation



Enacting a Compressive Force



Normal acceleration on user throughout simulation

- For this to work we need:
  - Maximum force of 1075.41 N
  - Maximum acceleration of 1.10 Gs
  - Maximum displacement of 0.78 m
  - Maximum Impulse of 928.77 N/s

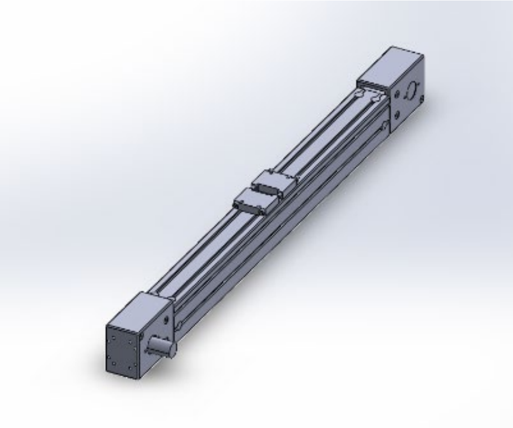
Mechanical Feasibility Analysis

Hardware: Belt Driven Linear Actuator

Cost: ~$3300 per unit

Models Options: Misumi MSA-SBH Series,

Macron Dynamics MSA-14S, Parker OSPE BHD Belt Actuator



Misumi MSA-SBH Series

Important Specs:

Speed	Actuation Length	Maximum Load	Maximum Acceleration	Maximum Vertical Moment
1-10 m/s	0.8-1.2m	50-567 kg each	~1-4 Gs	~180Nm

FOS Feasibility Analysis/Results

- **Analysis**
  - Max g-force = 1.1 g
  - Max user mass = 100 kg (1000 N)
  - Max platform mass = 50 kg (500 N)
  - Estimated max load = 270 kg (1600 N)
  - Linear actuator max vertical load = 567 kg
  - FOS = Up to 2.1 (depending on chosen actuator)
- **Result:** FOS of linear actuator = 2.1 > 2.0

MECH Feasibility Analysis Results

Requirement	Fulfillment	Feasibility
FR2: SKADI shall provide force and motion cues correlating to the phase in jump	1 Misumi linear actuator can support the needed weight throughout maximum states of simulation	YES
FR2: SKADI shall provide force and motion cues correlating to the phase in jump	Expected +0.10 *Gs* at peak compression	YES
FR3: SKADI shall be able to support the forces generated when used by the full range of USA Nordic athletes	Expected maximum velocity of 0.64 *m/s*	YES
FR8: SKADI shall be operable within a gymnasium while other athletes are adjacently training	Expected maximum necessary displacement of 0.78 *m*	YES

Mechanical Feasibility: Yes

Force Data Collection Feasibility (FOOT)

Force Data Feasibility Analysis Justification

All images courtesy of Kitronyx [8]

FR5: SKADI shall capture the data of the athlete's force profile.

1) **Data Collection** - Kitronyx Insole Sensor Kit, Snowboard 2, Snowforce Software
2) **Display Data** - Real time pressure distribution mapping
3) **Force Profile** - Calibration of CSV file to calculate the force values from the pressure distribution

Force data from CSV file

Kitronyx Insole Kit

Kitronyx Insole Kit in motion

Force Data Feasibility Analysis

Hardware: Foot Pressure Mapping System

Cost: $1,280

Model: Kitronyx Insole Sensor Kit

Important Specs:

User Equipped with Insole Kit [8]

Number of Sensing Pixels	Pressure Range	Frame Rate	Number of Display Pixels
118	180 kg	40 Hz	160

Force Data Feasibility Analysis

E4: The insoles will have a FOS of greater than 1.1 against structural failure

Maximum Force Supported by Sensors: 1765.8 N [8]

Expected Maximum Mass (m_{max}) : 100 kg

Expected Maximum Acceleration (a_{max}): 1.6 G = 15.696 m/s^2

$F_{max} = m_{max} \times a_{max} = (100 \text{ kg}) \times (15.696 \text{ m/s}^2) = \boxed{1569.6} \text{ N}$

Expected Maximum Force Generated: **1569.6** N

FOS = **1.13** > 1.1

FOOT Feasibility Analysis Results

Requirement	Fulfillment	Feasibility
FR5: SKADI shall capture the data of the athlete's force profile.	Kitronyx Snowboard 2 and Insole Sensor Suite	YES
FR2: The insoles will have a FOS of greater than 1.1 against structural failure.	A 100 kg athlete can undergo 1.6 Gs without device breaking	YES
E3: The pressure distribution data shall be mapped visually.	Kitronyx Snowforce software provides real time mapping and data logging	YES

Force Data Collection Feasibility:	Yes

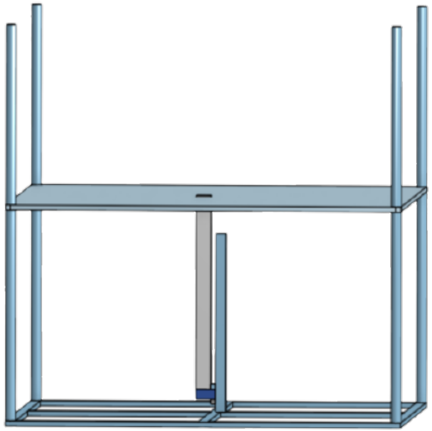
Financial Feasibility (COST)

Visual & Force Data Collection Costs

- Visual: ~$450
  - Oculus Quest 2: $300
  - Oculus accessories: $130
- Force Data Collection: ~$1300
  - Kitronyx Insole Sensor Kit: $1280

Mechanical Design Cost (1 Linear Actuator)

- Cost: ~$4000
- Meets minimum load requirements for the lowest cost
- Concerns:
  - High torques will be applied to actuator, could exceed limit
  - Max applied moment during simulation ~1000 Nm



Initial Financial Feasibility Analysis

- Initial cost estimate
- One linear actuator
  - Capable of supporting max load
  - High max torque

Subsystem	Estimated Cost
Mechanical	$4000
Visual Cues	$450
Force Data Collection	$1300
TOTAL	**$5750**

Financial Feasibility:	**No**

Final Financial Feasibility Analysis

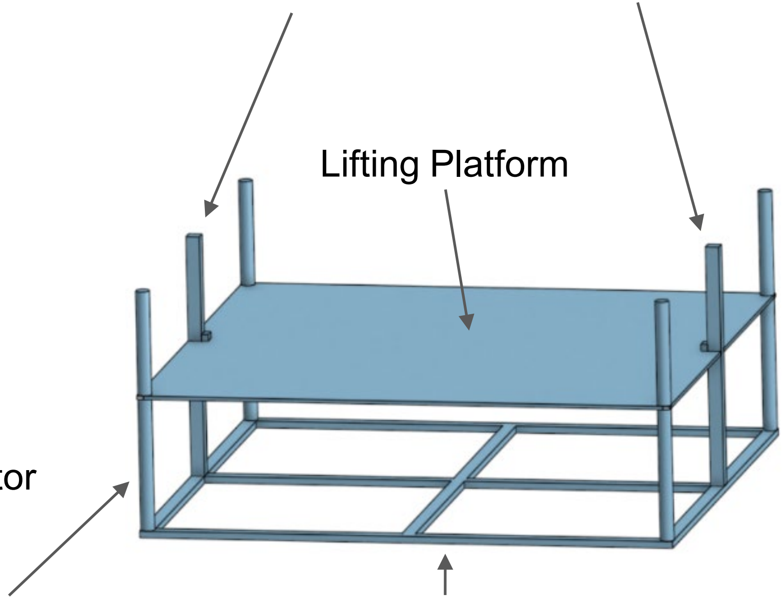
- Additional $5k from USA Nordic to address safety, time cost, and simplicity
  - Added an additional linear actuator
  - Reduces moments applied to each linear actuator

Subsystem	Estimated Cost
Mechanical	$7300
Visual Cues	$450
Force Data Collection	$1300
TOTAL	**$9050**

Financial Feasibility:	**Yes**

Mechanical Design Cost (2 Linear Actuators)

- Cost: ~$7300
- Improvements
  - Much less torque related concerns
  - User cannot swing into structural poles
  - Lower height
    - Improved user safety
    - Eliminates need for stairs
- Concerns
  - Will cost close to twice as much as single actuator



Status Summary & Future Work

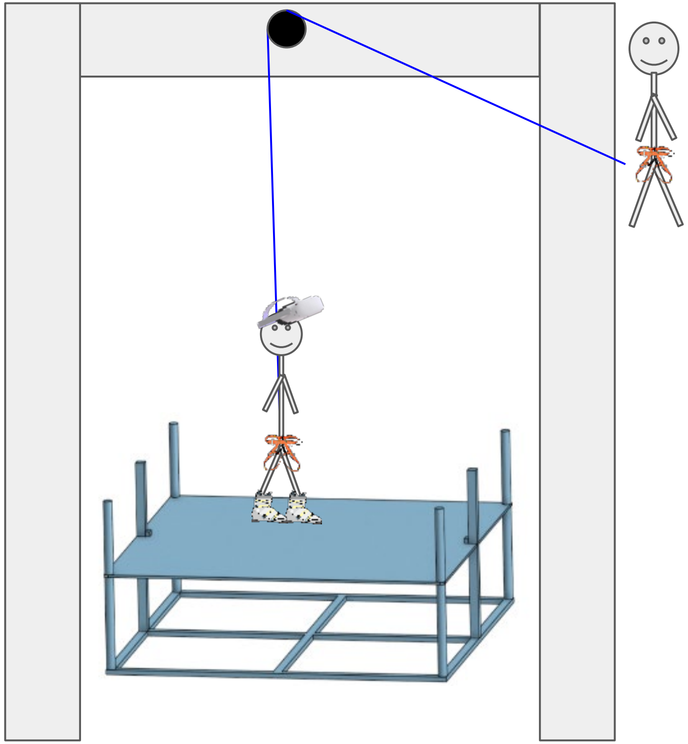
Presenter: Michael Schlittenhart

Section Outline

- Baseline Design Summary
- Feasibility Conclusion
- Future Work
- Plan of Action

Baseline Design Summary

- Oculus Quest 2
- Kitronyx piezoelectric sensors
- Moving platform
- Catching mechanism



Feasibility Conclusion

Label	Func. Req.	CPE	Description	Feasible?
VIS	FR1	E1	Headset will be able to display visual cues and be synchronized with physical cues.	Yes
MECH	FR2	E2	Provide analog force and motion cues to that of a standard ski jump to simulate proper jump timing. Sufficient load-bearing capabilities.	Yes
FOOT	FR5	E4	The pressure distribution data will be collected and mapped visually.	Yes
COST	Budget	Budget	The total monetary cost of SKADI is <$10k*	Yes
Overall Feasibility of Baseline Design				**Yes**

*Adjusted from initial $5k

Future Work

- Visual
  - Select visual cue presentation format
  - Check if VR software can be integrated with mechanical software
- Mechanical
  - Further define mechanical design
  - Select linear actuator
  - Load analysis on connection between platform and linear actuator
  - FBD comparison of platform and real ski jump
- Force Data Collection
  - Bluetooth communication and range
  - Force data processing and Calibration of the force output
  - Battery supply

Plan of Action

WORK BEFORE CDR								October				November			
Task	Duration [weeks]	Planned Start Date	Actual Start Date	Planned End Date	Deadline Date	Actual End Date	Week of:	10/11	10/17	10/24	10/31	11/7	11/14	11/21	11/28
Mechanical															
Redesign of PDR Baseline	1	10/13		10/17	10/20										
Selection of Linear Actuator	1	10/13		10/17	10/20										
Manufacturing Plan	3	10/17		11/7	11/10										
Manufacturing Diagrams	3	10/17		11/7	11/10										
Design Component Selection (nuts & bolts)	3	10/17		11/7	11/10										
Visual															
Visual Cue Format Selection	1	10/13		10/17	10/20										
Visual to Mechanical Software Integration	2.5	10/27		11/14	11/20										
Power Source Selection	2.5	10/27		11/14	11/20										
Foot Force															
Bluetooth Communication	1	10/13		10/20	10/25										
Force Data Processing	3	10/20		11/11	11/20										
Power Supply Method	2	10/15		10/29	11/1										
Force Data Callibration	2	11/1		11/11	11/20										
Systems															
Updating Requirements	3	10/13		11/7	11/10										
Verification & Validation Plans	2	10/24		11/7	11/10										
Risk Analysis	3	10/24		11/14	11/20										
Deliverables															
CDR Powerpoint Slides		11/7		11/15	11/29										

CDR Due

Acknowledgments

USA Nordic Team: Tim Tetreault, Jed Hinkley

Faculty Advisor: Dr. Melvin Rafi

PDR Reviewers: Blue Origin Team (SP4CE), Colin Claytor

Additional Help: Penina Axelrad

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Questions?

Supporting Materials

Links to Sections

Visual

Links to Slides

[Visual Feasibility Analysis - Hardware]

[Standalone VR Headset Trade Study]

Visual Feasibility Analysis - Hardware

Hardware: Oculus Quest 2

Cost: $500 for goggles + accessories

<u>Important Specs:</u>

RAM: 6GB

Storage: 128GB

Maximum Render Resolution: 5408 x 2736

Standalone VR Headset Trade Study

Standalone VR Headset Trade Study							
Criteria	Weight (%)	Oculus Quest 2	HTC Vive Focus 3	Pico Neo 3 Pro	Pico G2 4K	DPVR P1	DPVR P1 Pro 4k
Cost	40	3.5	1	2	3	5	3
Memory	25	4	5	4	3	1	1
Resolution per Eye	25	2	5	2	4	1	1
Passthrough	5	5	5	1	1	1	1
Battery Life	5	3	2	3	3	5	5
Weighted Score		**3.30**	**3.25**	**2.50**	**3.15**	**2.80**	**2.00**

Mechanical

Links to Slides

Baseline Design

Mechanical Feasibility Analysis

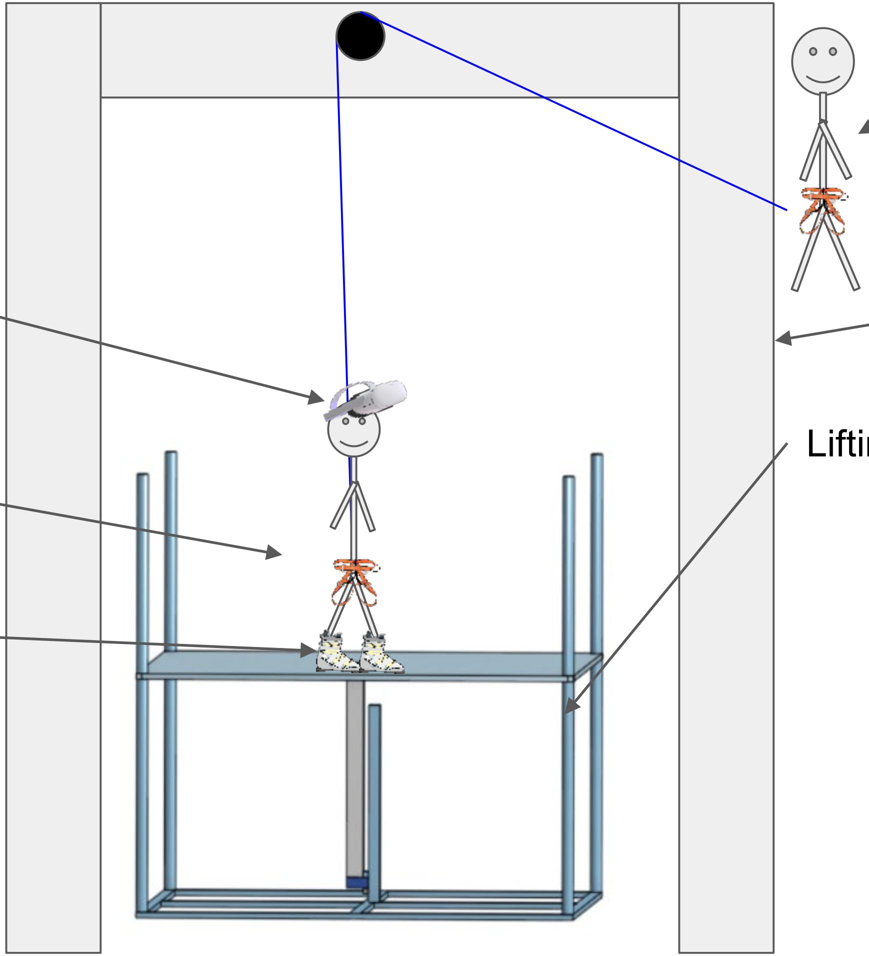
Linear Motion Trade Study

Baseline Design

VR Headset:
Oculus Quest 2

User

Force Data Sensors



Belay Mechanism,
Operated by 3rd Party,
Attached to scaffolding

Scaffold Structure to
hold Belay System

Lifting Mechanism

Mechanical Feasibility Analysis

Hardware: Screw Driven Linear Actuator

Cost: $3000-$6000 per unit

Models Options: Mcmaster-Carr 4106N61,

Sure Motion LAHP 33 Series, Oriental THK LM KR33 Linear Actuator

Important Specs:

Speed	Actuation Length	Maximum Load	Maximum Acceleration
400-1000mm/s	500-1000mm	~8-20kg each (depends on speed)	0.3-1g’s

Mechanical Feasibility Analysis

Hardware: Roller Bearing

Cost: $26 per unit

Models Options: 010-2RS Bearing 50x80x16 Sealed Ball Bearings

Diameter: 50 mm

Mechanical Feasibility Analysis Results

Actuator	Belt Driven	Screw Driven
Fulfills Requirement?	Yes	Yes
Description of Functionality	Can produce desired forces and speed within a reasonable distance	Higher speeds but deform while under predicted loads
Feasible?	**Yes**	**No**

Mechanical Feasibility: Yes

Mechanical Hardware Considerations: Linear Motion Trade Study

Criteria	Weight (%)	Screw Driven Actuator	Grade	Belt Driven Actuator	Grade	DIY Linear Actuator	Grade	Hydraulics	Grade	Pneumatics	Grade
Length	20%	Difficult to find stroke length larger than 1000mm (screw bends)	2	Can be as long as 3 meters	5	Based off screw driven actuator, difficiult to achiever more than 1000mm	2	Can be more than 1000mm long	5	Difficult to find over 2000mm	3
Speed	20%	Range from <1m/s To 3m/s	4	Up to 10m/s	5	Range from <1m/s to 3m/s	4	Very Slow, (in/min)	1	Speed is dependent on load, but can achieve >1m/s	3
Force	20%	Can quickly switch directions, loses torque with longer ball screw	4	Belt can slip, cannot apply excessive force	3	Can quickly switch direction, loses torque with longer ball screw	4	Can supply lots of force, but has difficulty changing direction	3	Force applied is variable with position	2
Load Bearing	20%	Can support several hundred kg	5	Can hold ~100kg (ideally we have 4), belt can slip	3	Would need to conduct stress tess, likely capable of supporting athlete	4	Can Support any load	5	Can support several hundred pounds	5
Cost	10%	~$3000+ each	2	~$2000+ each	3	<$1000 each	5	~$1000 each	4	~$1000 each	4
Integration Complexity	10%	Easy to program, and easy to integrate with platform	5	Easy to program, and easy to integrate with platform	5	Would needed to be designed, easy to integrate after	3	Very difficult to program, requires fluid	1	Difficult to program, force applied changes with mass	1
	100%										
Average Score		Screw Driven Actuator	3.666666667	Belt Driven Actuator	4	DIY Linear Actuator	3.666666667	Hydraulics	3.166666667	Pneumatics	3
Weighted Score			3.7		4		3.6		3.3		3.1

Force Data Collection

Links to Slides

Next Steps

- Bluetooth communication with Snowforce software and computer
- Bluetooth communication distance
    - If customer is using Kitronyx kit on the real slope, we want to ensure that the Snowboard 2 can maintain communication with the computer
- Data processing
    - Create a program to display the force data from the CSV file
    - Test using simulated data
    - Simple interface so that coaches can use
- Test plans for calibration
    - Calibration feasibility

Kitronyx Insoles Specifications[8]

Electronics

Specifications	Value
Dimensions (mm)	109x71x29
Number of Sensing Pixels	160 (16x10)
Frame Rate (Hz)	40
Computer Interface	USB
Operating System	Windows 7-10
Power Supply	USB Powered

Sensors

Specifications	Value
Sensor Size (mm)	235, 270, 280
Thickness (mm)	<1
Cable Length (mm)	150
Pressure Range (kg)	180

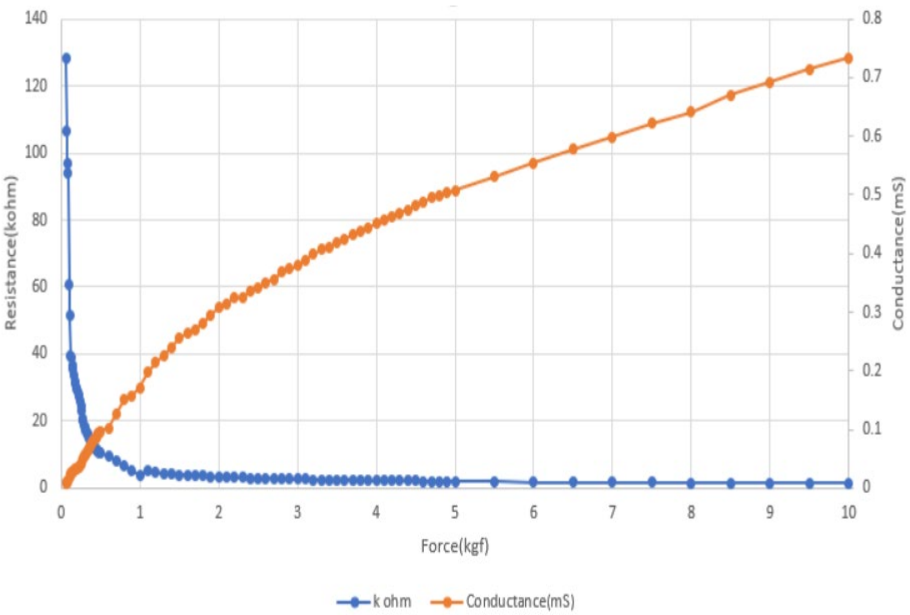
Calibration

Calibration is necessary to get physical pressure values from the pressure distribution

- Put an object of know mass on the sensor
- Record force and measure the ADC sum
- Using A and F you can get a linear relationship

Physical pressure not an accurate result

- Sensor ADC curve nonlinear
- Each pixel has a different response



Relationship between force and ADC output [10]

FOS: 1.1

FOS is 1.1 because the customer would like the ability of collect force data from a real ski jump.

An athlete (100 kg) pulls a maximum of 1.6 G will generate a maximum force of 1569.6.

From data sheet, sensor can accommodate up to 180 kg of mass or 1765.8 N.

1765.8 N / 1569.6 N = 1.125

Therefore FOS > 1.1

Force Trade Study

Foot Force Profile Trade Study					
Criteria	Weight (%)	Kitronyx	NURVV	PPS TactArray	Piezoelectric
Cost	20	2	4	3	5
User Complexity	13	5	4	4	3
Integrability	15	4	3	3	1
Fidelity	5	3	1	5	4
Accuracy	20	4	2	5	3
Comfort	12	5	5	3	4
Battery Life	5	5	5	5	5
Data Aquisition	10	5	4	4	2
Weighted Score		**3.95**	**3.47**	**3.83**	**3.27**

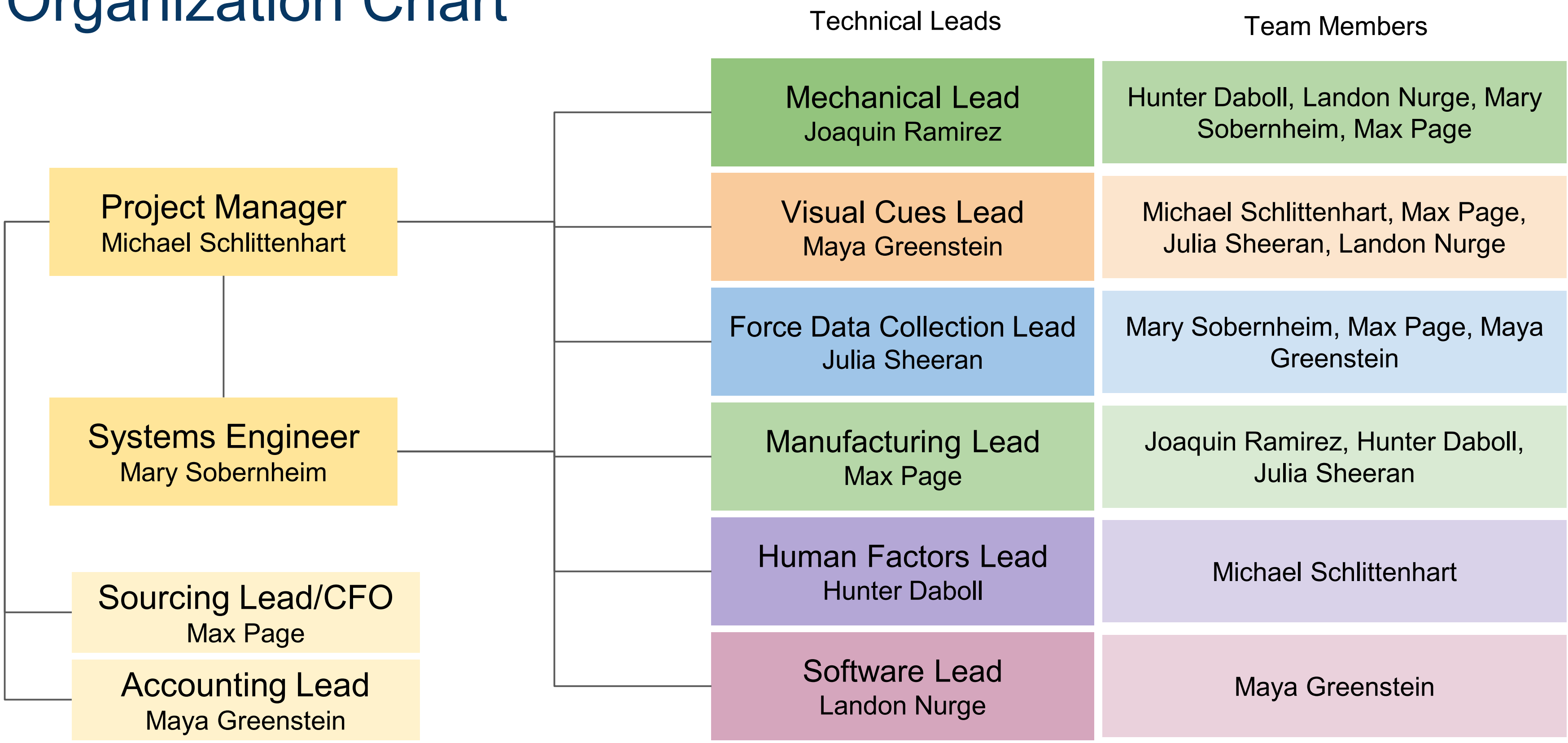
Trade study of the options investigated to collect the foot force data

Logistics

Links to Slides

[Organization Chart]

Organization Chart



SKADI
SKI JUMP SIMULATOR

Budget

USA NORDIC

Links to Slides

Budget Breakdown - Visual

Budget Breakdown - Mechanical

Budget Breakdown - Force Data Collection

Budget Breakdown - Visual

Oculus Quest 2 Base Headset (128 GB Storage)	$300
Elite Strap, Battery pack, Carrying Case	$130
TOTAL	$430

Budget Breakdown - Mechanical: Baseline

Linear Actuator	$3300
Structural Elements	$600
Bearings	$100
TOTAL	$4000

Budget Breakdown - Mechanical: New Budget

Linear Actuator (x2)	$6600
Structural Elements	$600
Bearings	$100
TOTAL	$7300

Budget Breakdown - Force Data Collection

Kitronyx MP2513PLUS Insole Sensor Kit	$1300
TOTAL	$1300