Earth-Based Analogs & Modeling for Exercise Biomechanics in Space

Dec. 12th, 2018

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Johnson Space Center

& University of South Florida

Outline

- **University Collaboration**
- **Digital Astronaut Simulation**
- **Experimental Study**
- **Results & Takeaways**
- **Next Steps**

University Collaboration

Digital Astronaut Simulation

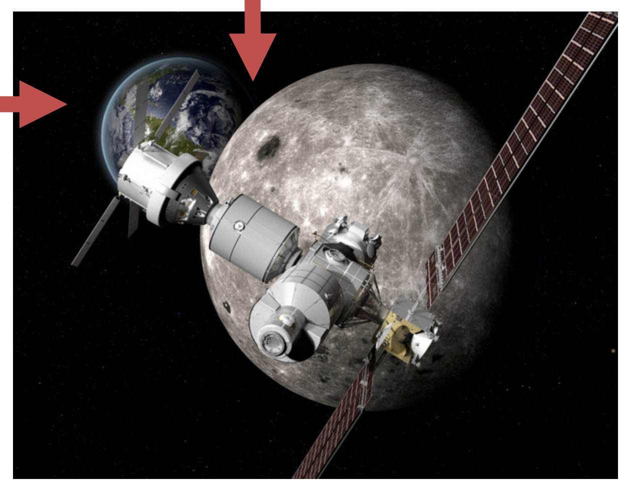
Experimental Study

Results & Takeaways

Next Steps

Center for Assistive, Rehabilitation & Robotics Technologies (CARRT) @ USF

NASA Space Technology Research Fellowship (NSTRF17)



University Collaboration

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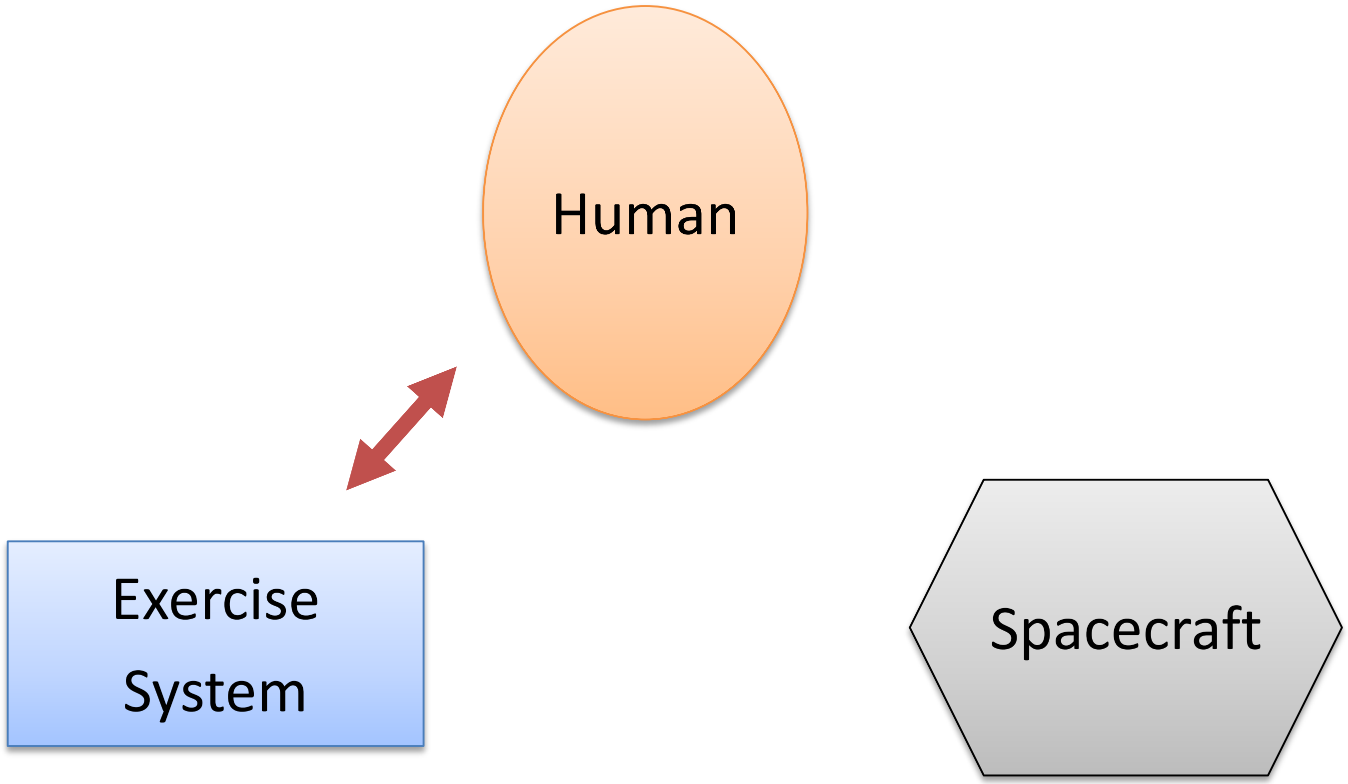
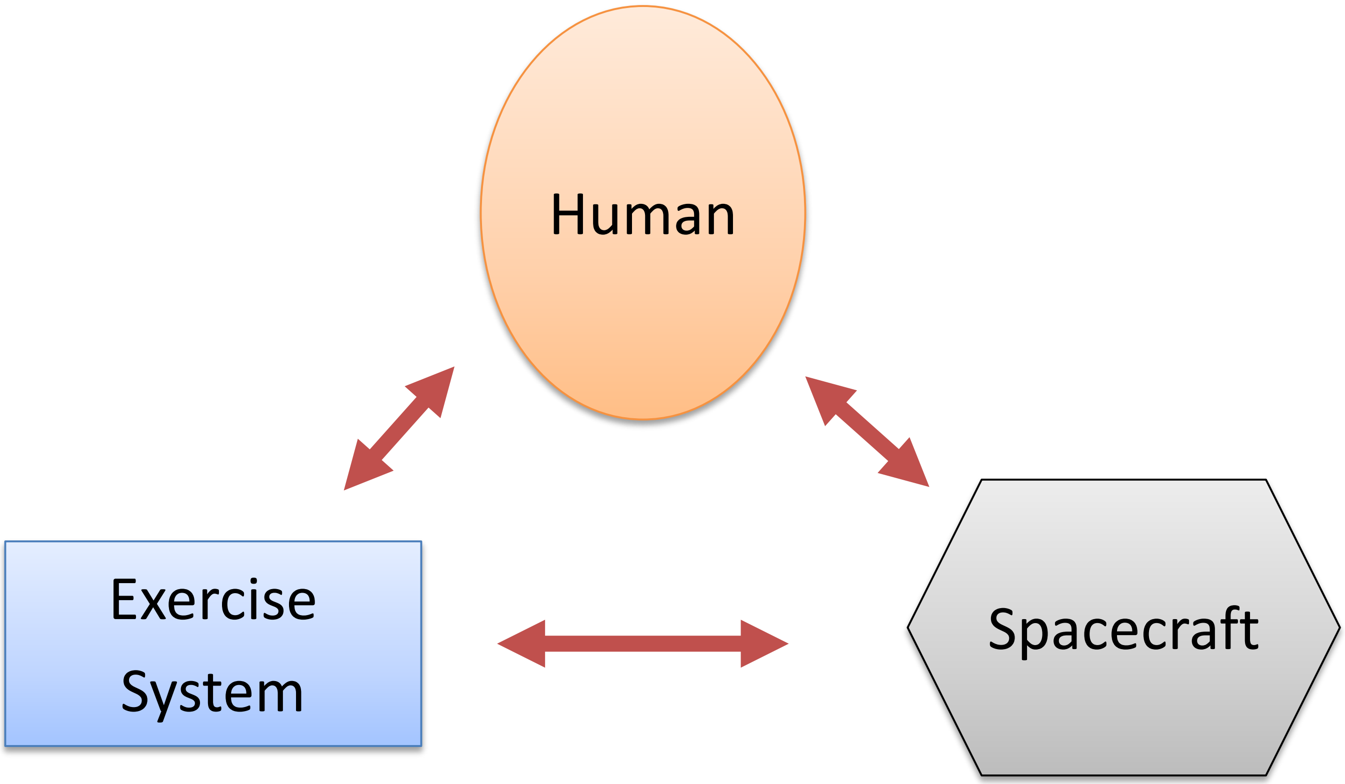
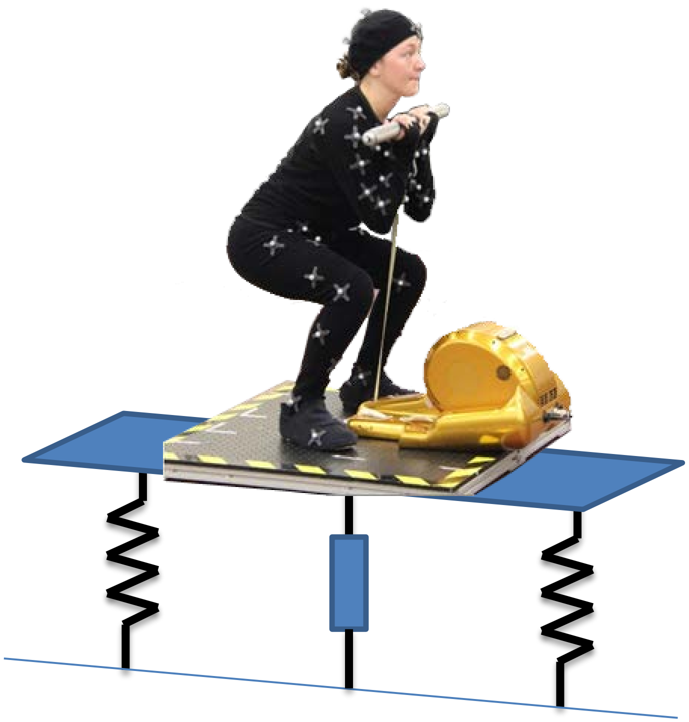
Digital Astronaut Simulation (DAS)

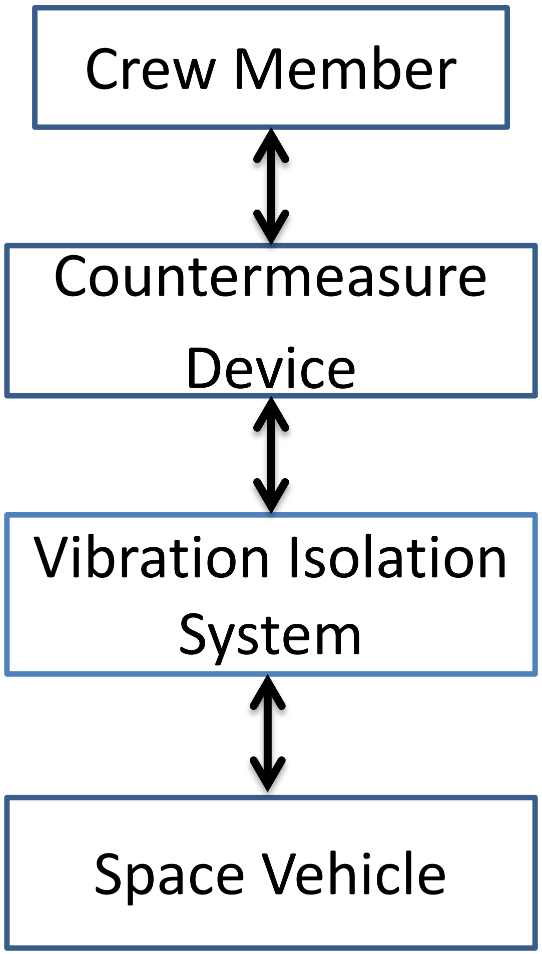


Digital Astronaut Simulation (DAS)

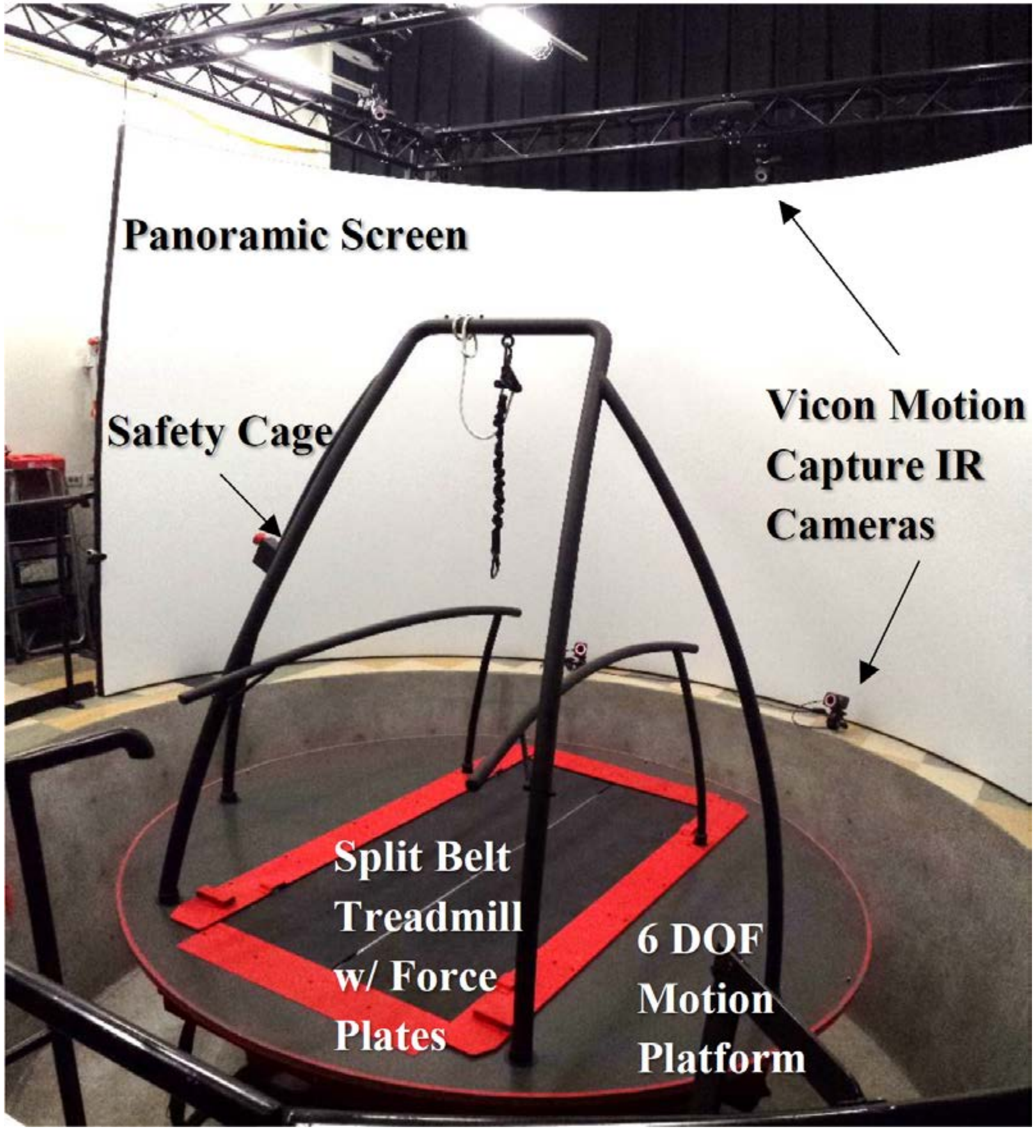


Vibration Isolation System (VIS)





Computer Assisted Rehabilitation Environment (CAREN) @ USF



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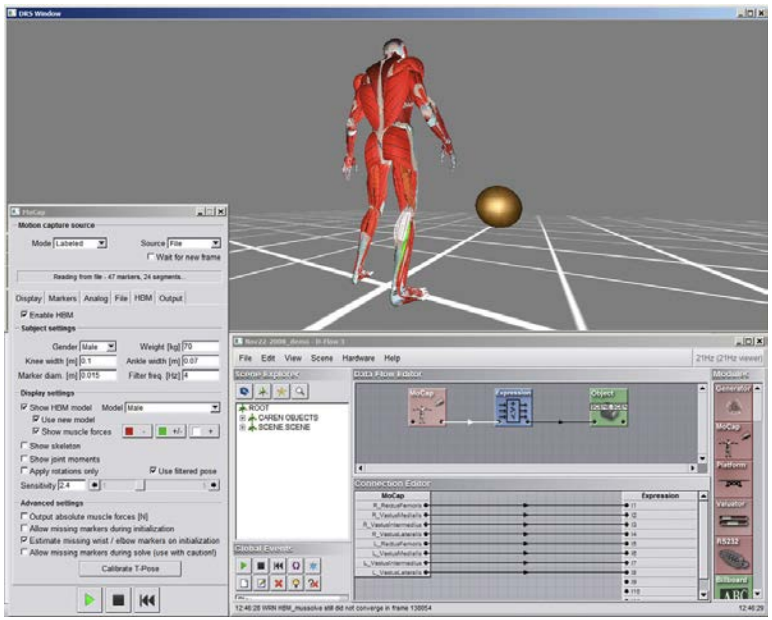
Computer Assisted Rehabilitation Environment (CAREN) @ USF

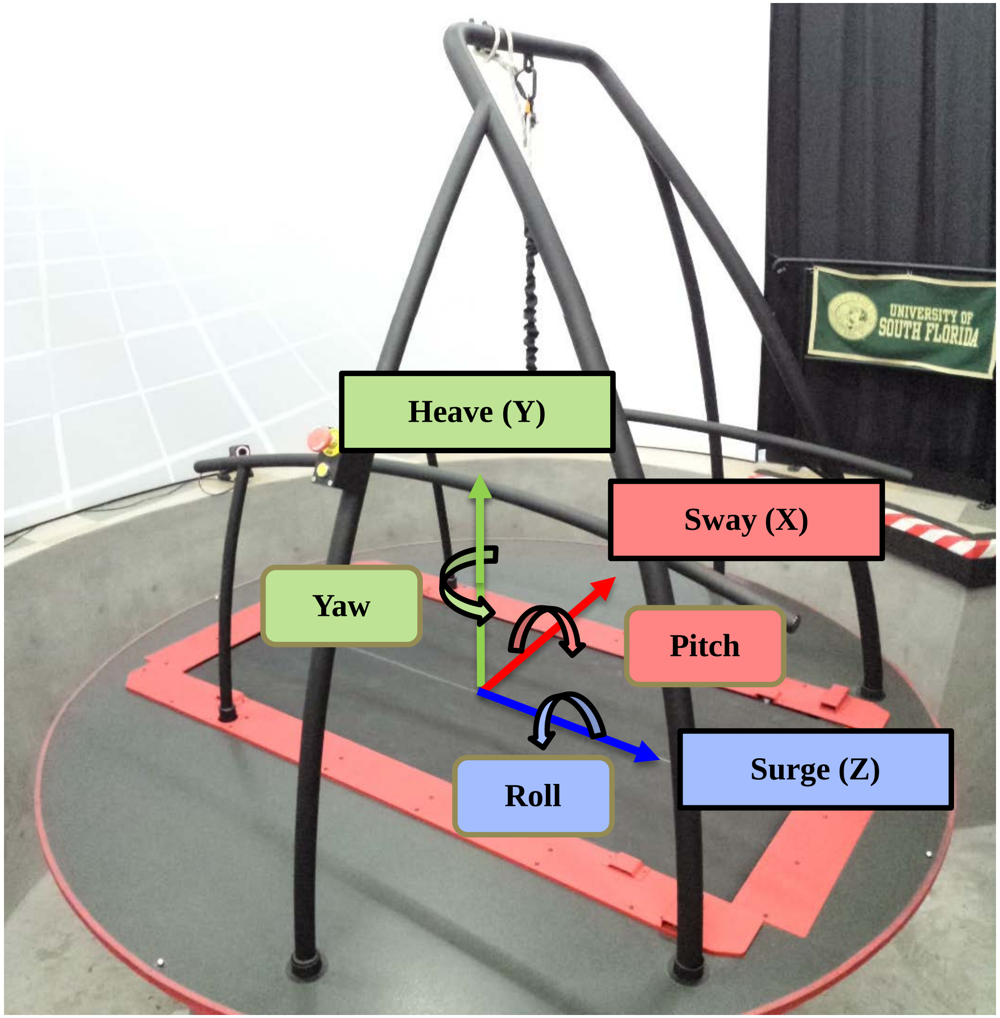
Human Body Model

van den Bogert, A.J., Geijtenbeek, T., Even-Zohar, O. et al. A real-time system for biomechanical analysis of human movement and muscle function. Med Biol Eng Comput (2013) 51: 1069.

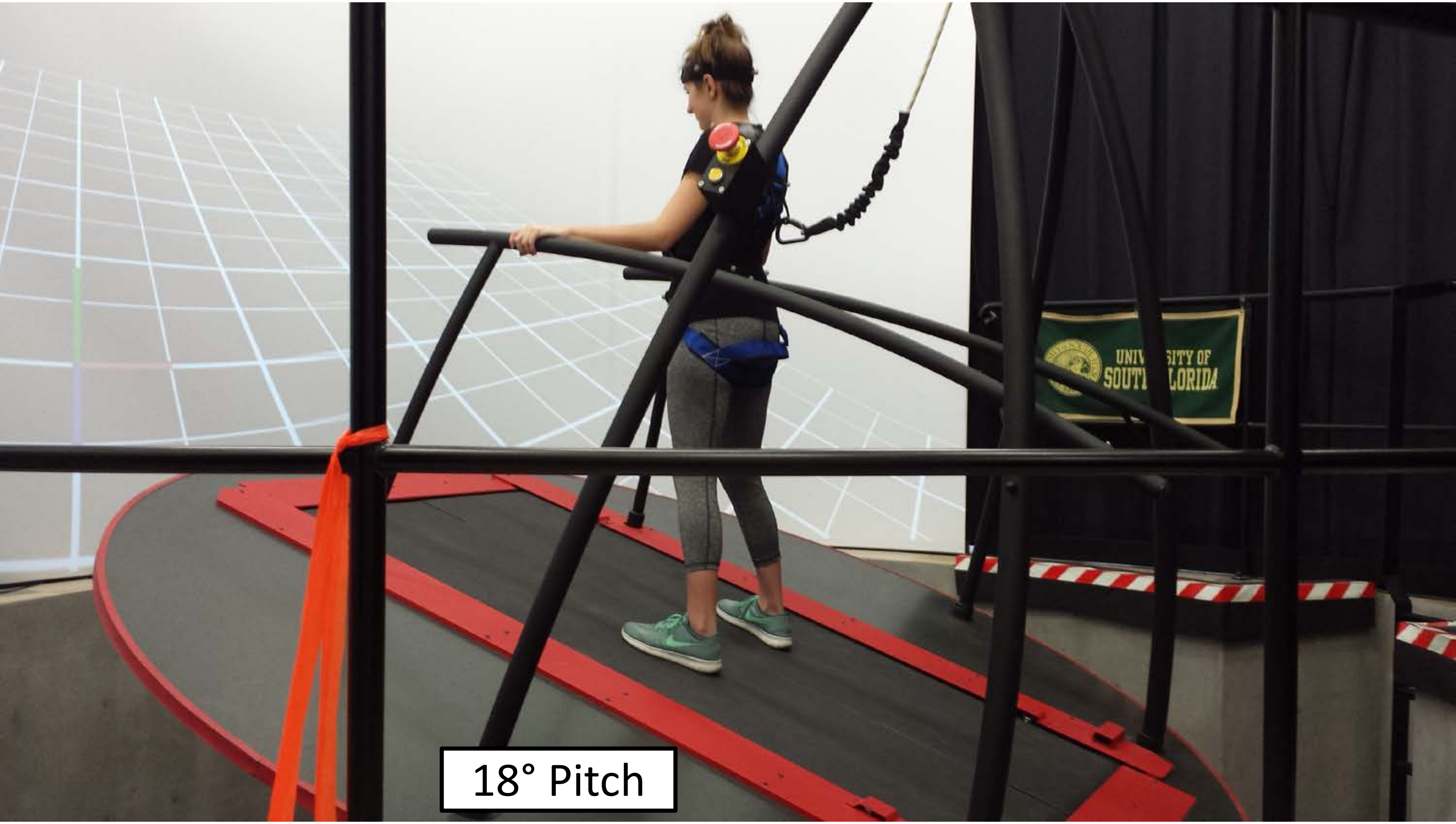


Analog & Digital Signals

Computer Assisted Rehabilitation Environment (CAREN) @ USF



Computer Assisted Rehabilitation Environment (CAREN) @ USF



Specific Objectives

1. To develop proof-of-concept for ground based environment for human-in-the-loop testing of VIS dynamics

2. To study the effect of platform motion on human kinematic and kinetic response while completing resistive and aerobic exercise.

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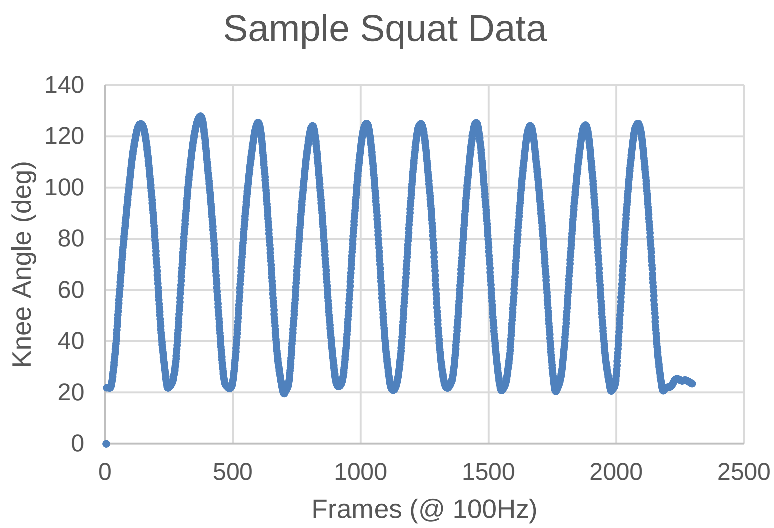
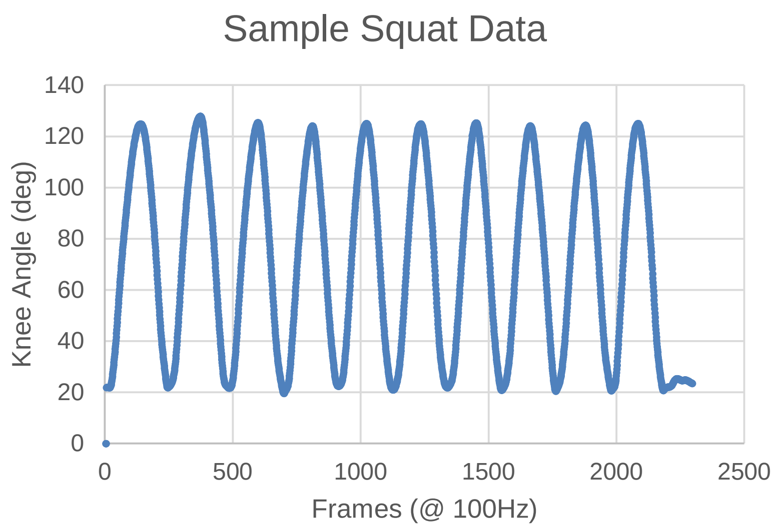
- DOFs of Interest:
  - 1 Translational
  - 1 Rotational
- Exercises of Interest:
  - Squats
  - Rowing
- Parameters of Interest:
  - Force
  - Motion

Theory



Bulk motion: Sinusoidal

Theory



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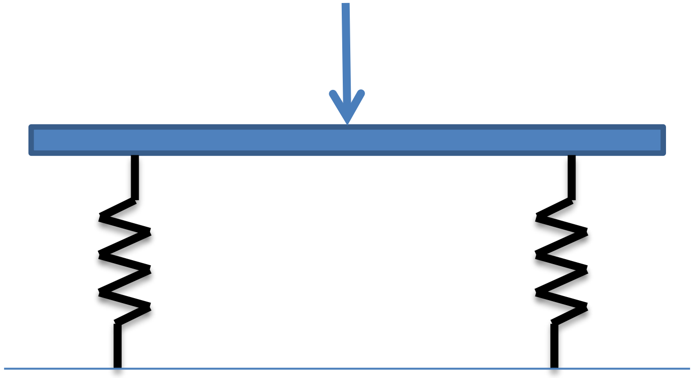
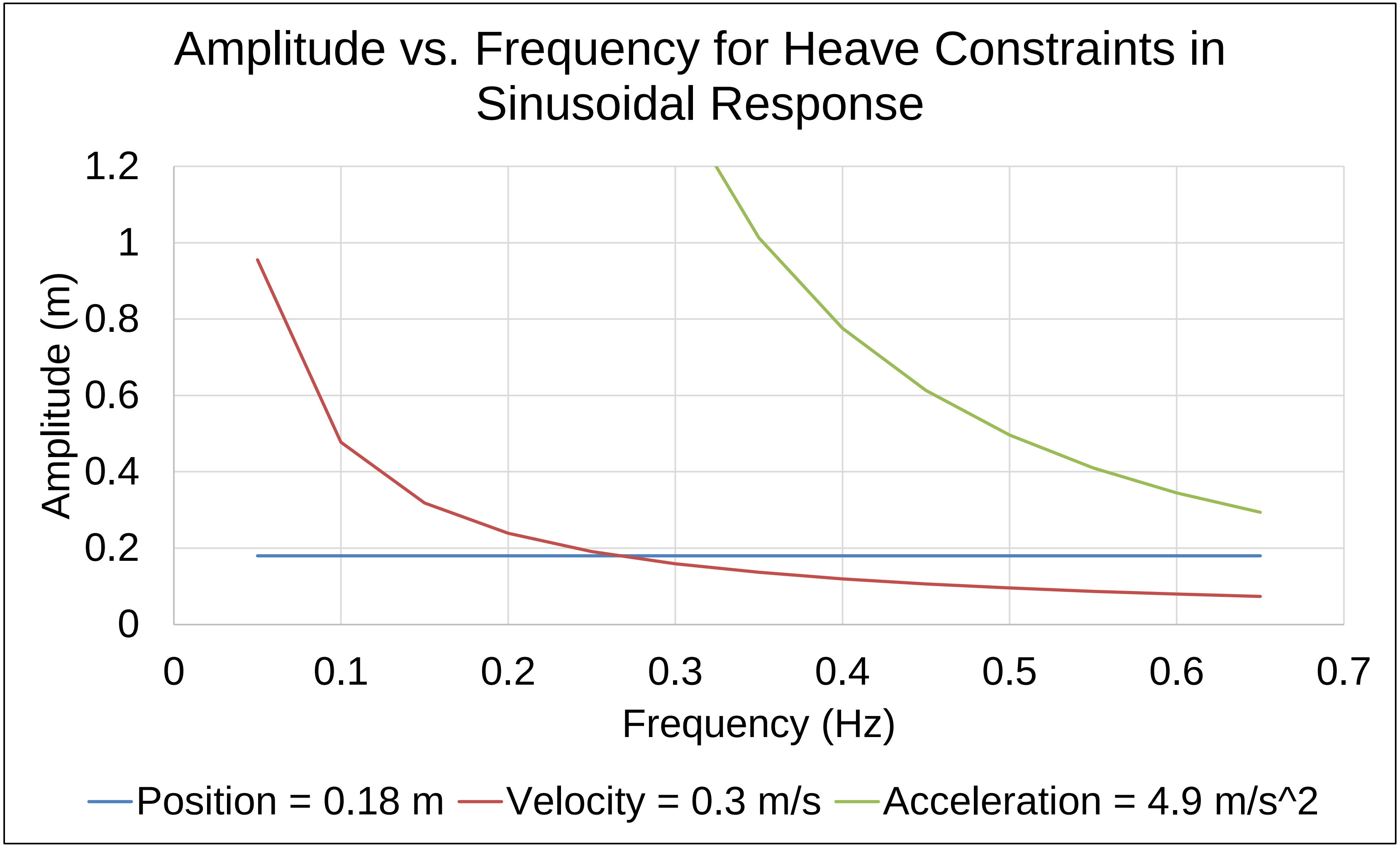


<u>Platform Dynamics:</u>

$$y(t) = A\sin(2\pi f t)$$

Constraint Determination



Experimental Design

Exercise & Platform Motion Frequencies

Frequencies Selected	Reason
0.10 Hz	ARED MILT & ISS Acceleration Environment
0.35 Hz	ARED MILT & midway point
0.60 Hz	ARED MILT & exercise point of interest
Self-selected	Nominal

Participants instructed to match platform motion

Experimental Design

- **IRB Approved Human Subject Testing on CAREN**

System Components:
- 2 DOF of motion platform

Instrumentation:
- Motion Capture – Kinematics
- Force Plate Measurement – Kinetics

Environmental Distinctions:
- 1G
- No external weight

Experimental Method: Subjects

N = 4

Subject Designation	Gender	Age	Height (m)	Weight (lbs / N)
S1	Female	18	1.73	136.0 / 605.0
S2	Female	22	1.62	121.2 / 539.1
S3	Female	44	1.60	148.2 / 659.2
S4	Male	22	1.86	172.2 / 766.0

Inclusion Criteria

1. Be between the ages of 18 and 65 years old
2. Have no physical impairments
3. Be able to complete exercise motions such as squats and vertical rows

Participation

1 session, ~2 hours

Experimental Method: Pre-Test Preparations

Training

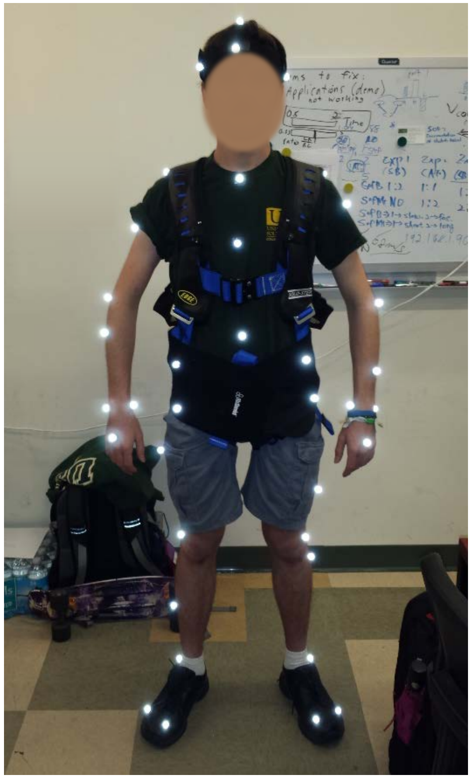
- Exercise Instruction
- Example Videos
- Instructed to match frequency of platform motion

Measurements

- Height & Weight
- Individualized Subject Parameters

Preparations

- Marker placement for motion capture



Experimental Method: Trials

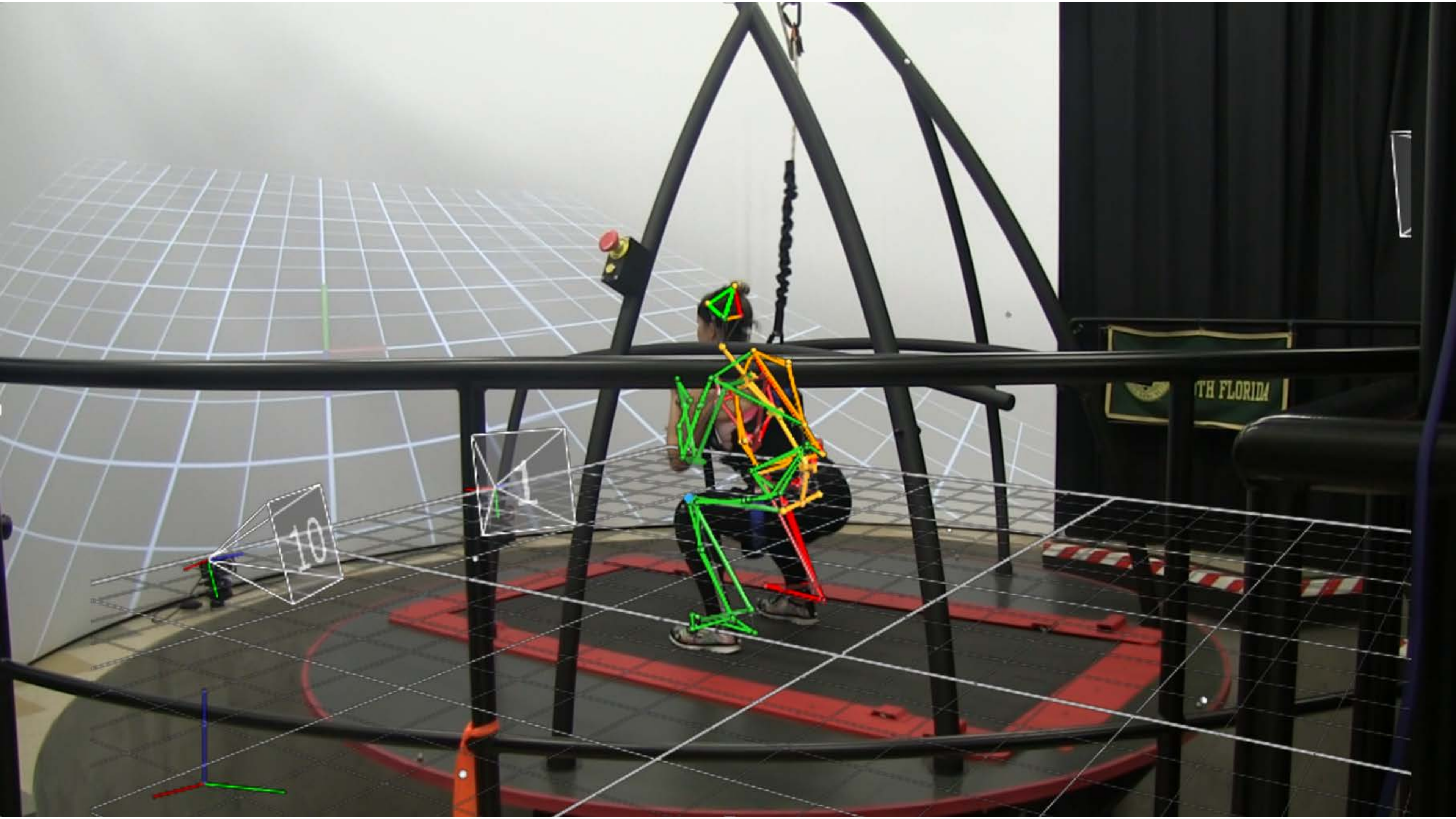
Squat:

#	Exercise	Heave Frequency	Heave Amplitude	Pitch Freq	Pitch Amp
3	Baseline Squat	N/A (Static)	N/A (Static)	N/A	N/A
4	Squat	0.10 Hz	Baseline Measured	N/A	N/A
5	Squat	0.35 Hz	Baseline Measured	N/A	N/A
6	Squat	0.60 Hz	Baseline Measured	N/A	N/A
7	Squat	Baseline Measured Hz	Baseline Measured	N/A	N/A

Row:

#	Exercise	Heave Frequency	Heave Amplitude	Pitch Freq	Pitch Amp
8	Baseline Row	N/A (Static)	N/A (Static)	N/A	N/A
9	Row	0.10 Hz	Baseline Measured	N/A	N/A
10	Row	0.35 Hz	Baseline Measured	N/A	N/A
11	Row	0.60 Hz	Baseline Measured	N/A	N/A
12	Row	Baseline Measured Hz	Baseline Measured	N/A	N/A
13	Row	Baseline Measured Hz	Baseline Measured	Baseline Measured Hz	0.5 deg
14	Row	Baseline Measured Hz	Baseline Measured	Baseline Measured Hz	1 deg
15	Row	Baseline Measured Hz	Baseline Measured	Baseline Measured Hz	2 deg
16	Row	Baseline Measured Hz	Baseline Measured	Baseline Measured Hz	3 deg

Testing



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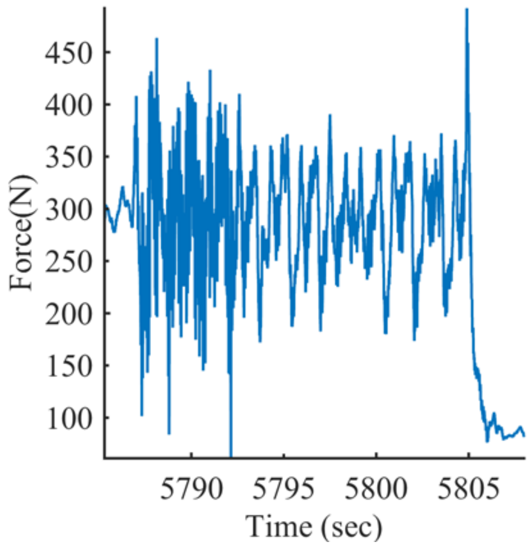
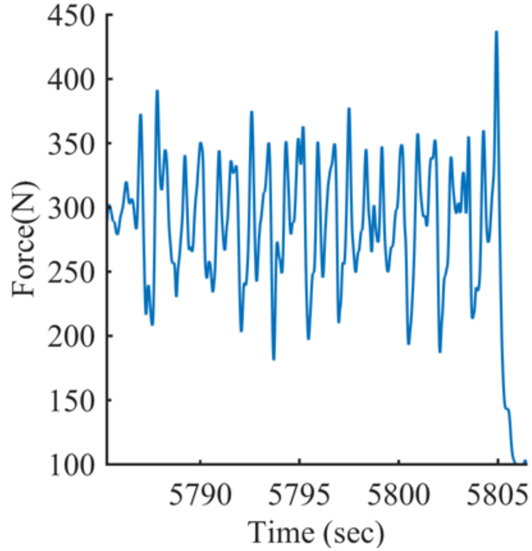
Kinetic Data Processing

- **Data Extraction**
- **Filtering**

- **Computations**
  - Resultant Force
  - Average Maximum Force
  - Average Force Range
  - Force Frequency Matching



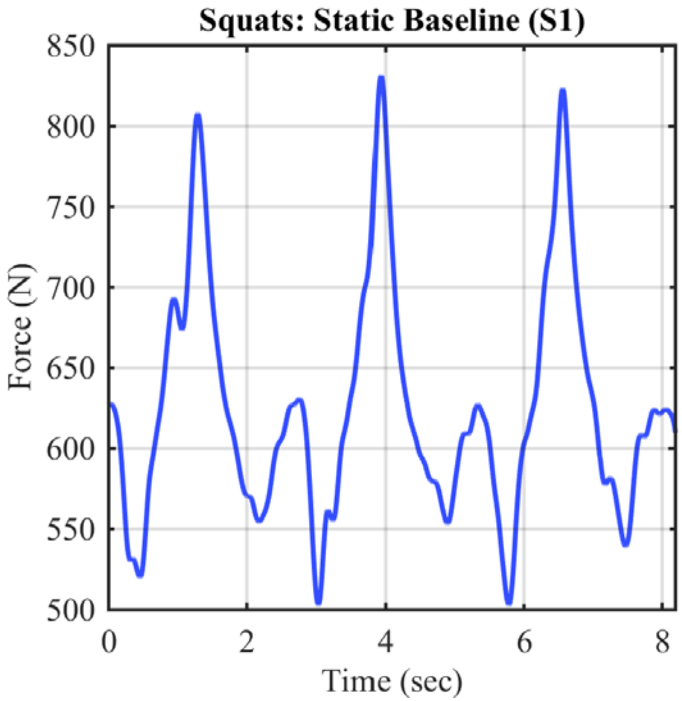
Unfiltered

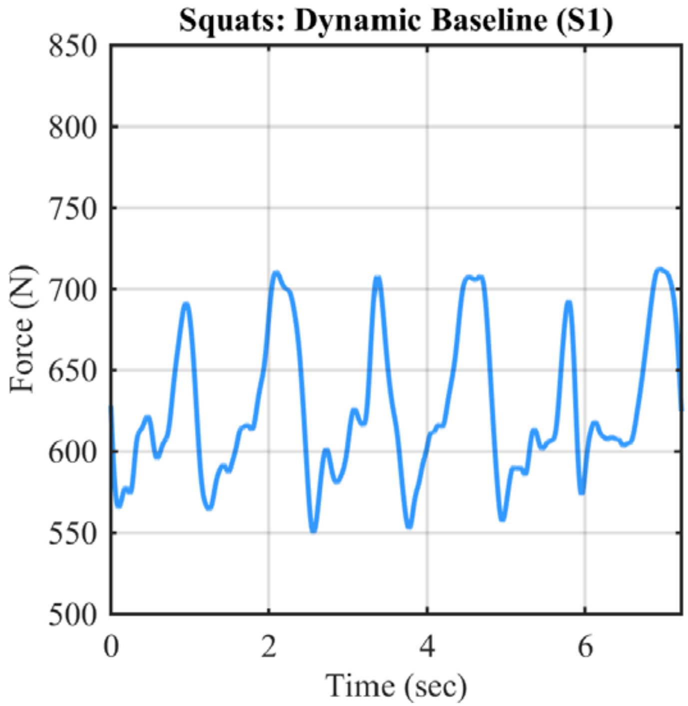


Filtered

Kinetic Results: Ground Reaction Force Profiles

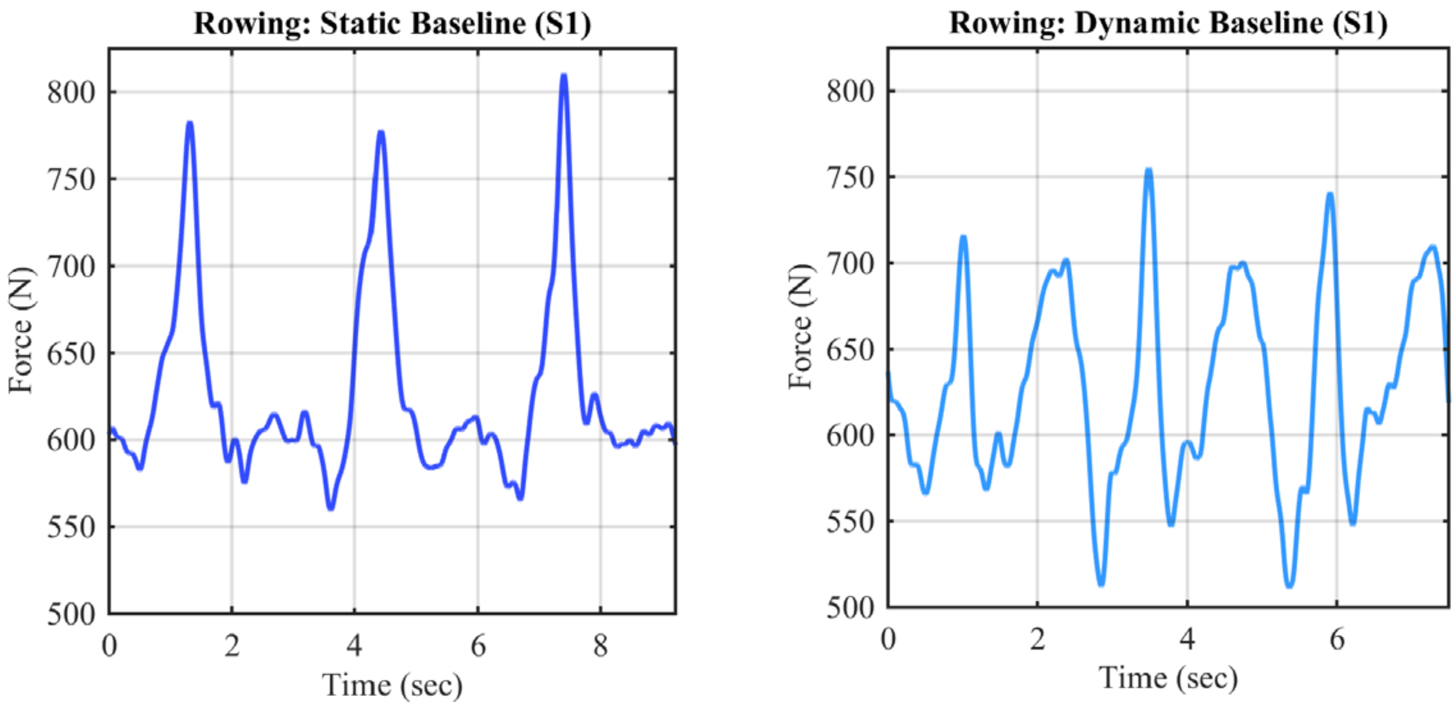
Squats





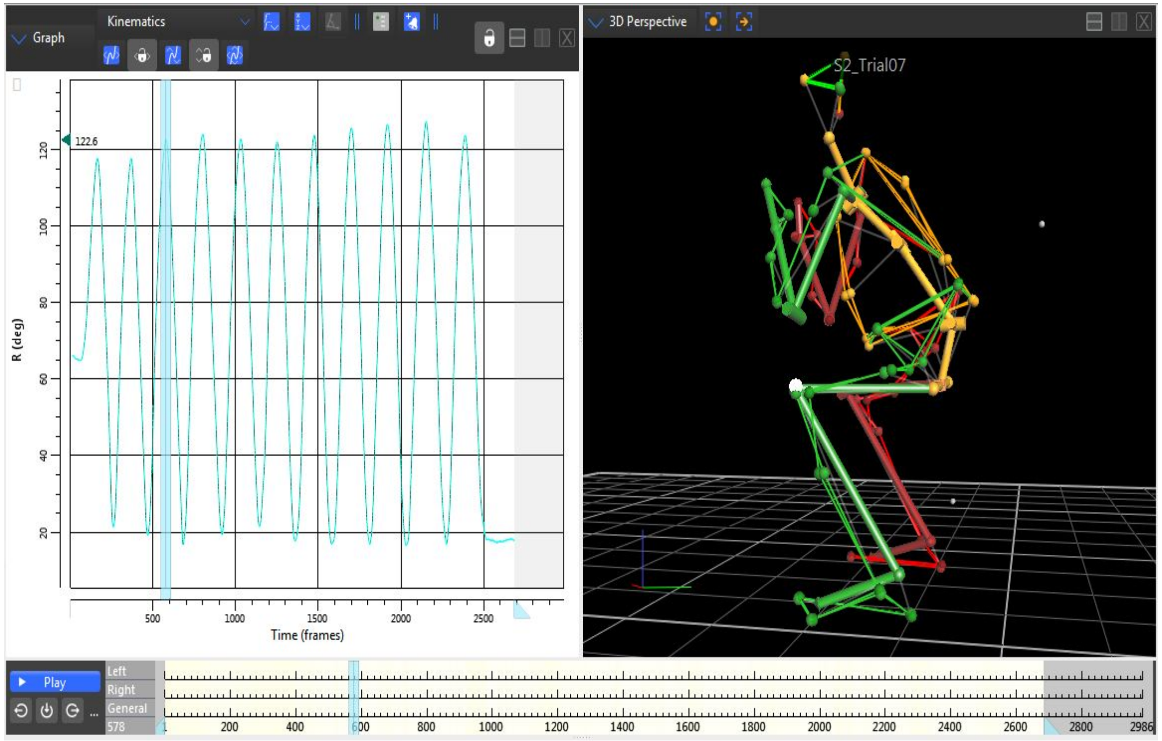
Kinetic Results: Ground Reaction Force Profiles

Rows

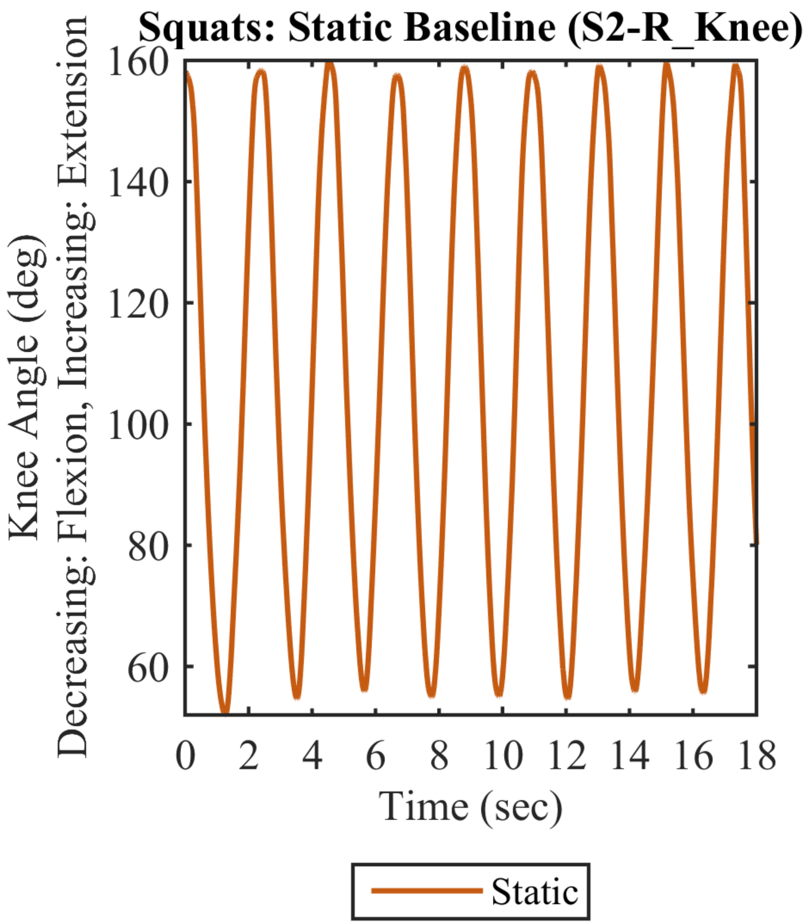


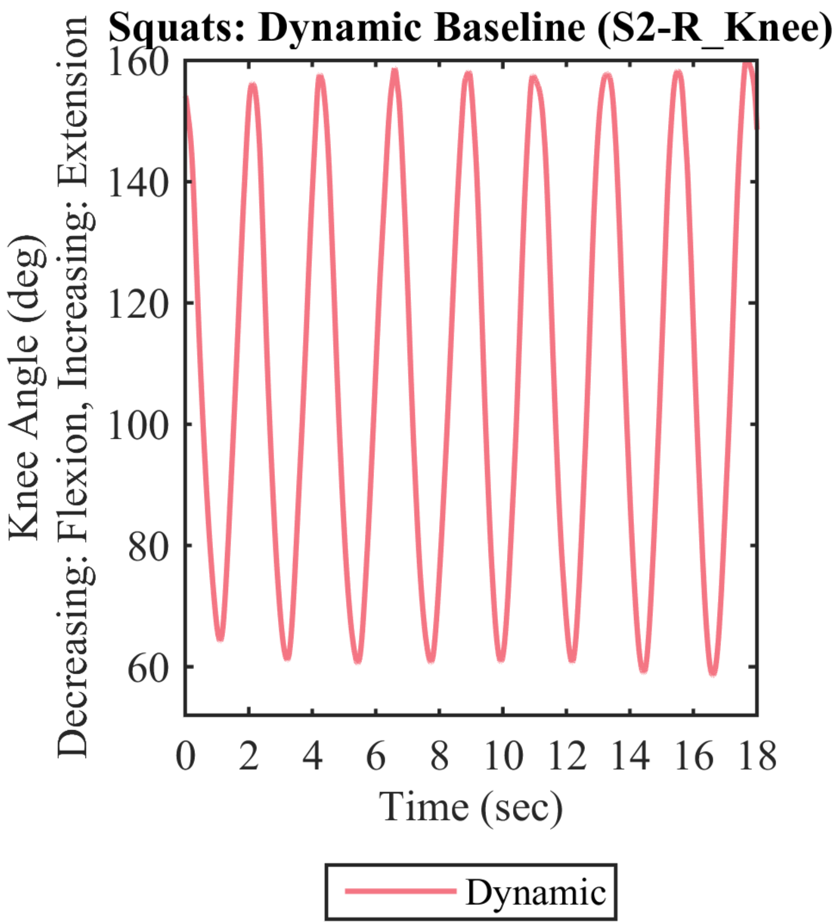
Kinematic Data Processing

- **Data Cleaning**
- **Functional Skeletal Model**
  - Calculates Joint Center
  - Joint Angles
- **Computations**
  - Joint Angle ROM



Kinematic Results





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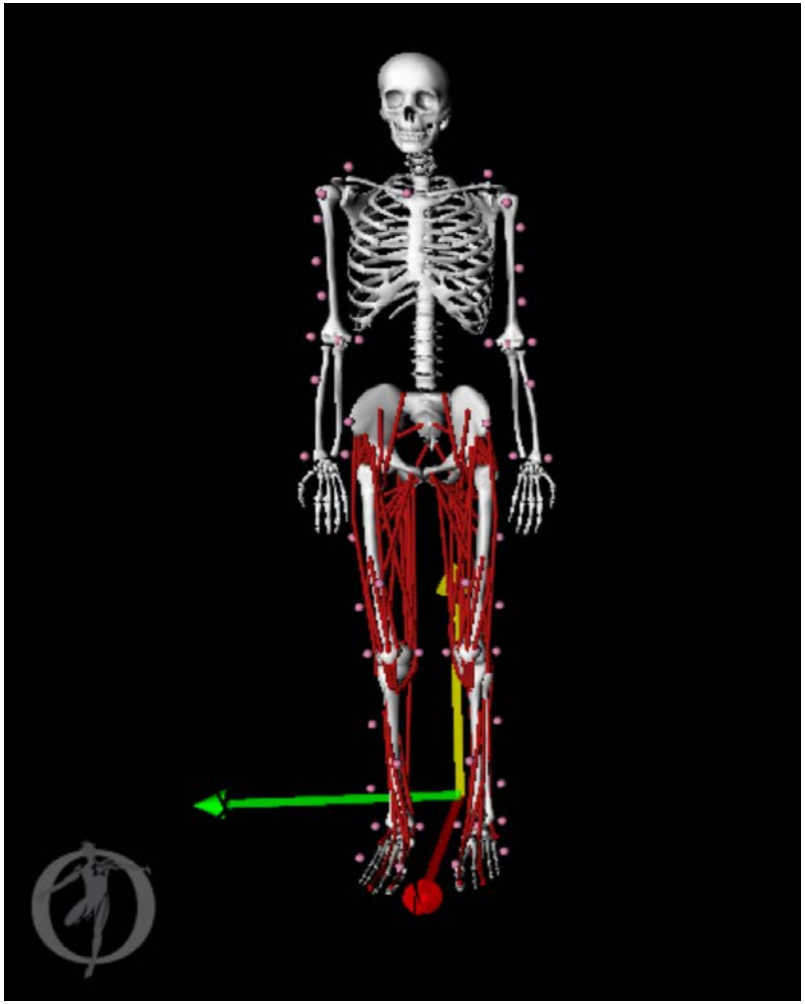
OpenSim



OpenSim, displaying: Rajagopal, Apoorva, et al. "Full-Body Musculoskeletal Model for Muscle-Driven Simulation of Human Gait." IEEE Transactions on Biomedical Engineering 63.10 (2016): 2068-2079. (2016)

1. Scaling
2. Inverse Kinematics
3. Inverse Dynamics
4. Static Optimization

OpenSim: http://opensim.stanford.edu/

Seth, A., Hicks J.L., Uchida, T.K., Habib, A., Dembia, C.L., Dunne, J.J., Ong, C.F., DeMers, M.S., Rajagopal, A., Millard, M., Hamner, S.R., Arnold, E.M., Yong, J.R., Lakshmikanth, S.K., Sherman,n M.A., Delp, S.L. OpenSim: Simulating musculoskeletal dynamics and neuromuscular control to study human and animal movement. Plos Computational Biology, 14(7). (2018)

Delp, S.L., Anderson, F.C., Arnold, A.S., Loan, P., Habib, A., John, C.T., Guendelman, E., Thelan, D.G. OpenSim: Open-source software to create and analyze dynamic simulations of movement. IEEE Transactions on Biomedical Engineering , vol 55, pp 1940-1950. (2007)

JSC Facilities

Active Response Gravity Offload System (ARGOS)

Prototype Immersive Technology Lab (PIT)

Forward Work

- **Enhancing CAREN as an analog for a passive VIS**
- **Development for active VIS**
- **PIT & ARGOS data collections**
- **VIS analyses and design using motion capture & force data from human-in-the-loop testing**
- **Incorporation of data feedback in exercise systems**

Contact

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More information on this topic:

Lostroscio, Kaitlin, "Developing Motion Platform Dynamics for Studying Biomechanical Responses During Exercise for Human Spaceflight Applications" (2018). Graduate Theses and Dissertations.

https://scholarcommons.usf.edu/etd/7191