**Human Modeling and Experimentation under Artificial Gravity using the MIT Compact Radius Centrifuge**

**Motivation**
Humans suffer strong physiological deconditioning during space missions, primarily due to the weightlessness conditions. Some of these adverse consequences include bone loss, muscle atrophy, sensory-motor deconditioning, and cardiovascular adaptation, which may lead to orthostatic intolerance when astronauts are back on Earth. In order to mitigate the negative effects of weightlessness, several countermeasures are currently in place such as very intensive exercise protocols or the intake of nutrition supplements. However, despite these countermeasures, astronaut physiological deconditioning persists, highlighting the need for new approaches to maintain the astronauts’ physiological state within acceptable limits.

**Artificial Gravity**
Artificial gravity has long been suggested but never tested as a comprehensive countermeasure that is capable of challenging all the physiological systems at the same time, therefore maintaining overall health during extended weightlessness. Ground studies have shown that intermittent artificial gravity combined with ergometer exercise is effective in preventing cardiovascular and musculoskeletal deconditioning. However, confounding factors between the studies make it very difficult to draw clear conclusions about the right combination of parameters needed to maintain physiological conditioning in space.

**Objectives**
To investigate human physiology during ergometer exercise under artificial gravity (AG) generated by a short-radius centrifuge

- Empirically investigate the effects of different AG levels and exercise workload intensities
  - Cardiovascular system
  - Musculoskeletal system
  - Motion sickness & comfort
- Develop a cardiovascular model to capture the effects of AG + exercise
  - Understanding of cardiovascular responses using new AG configurations: gravity gradient, gravity level, exercise intensity, and cardiovascular 0g-adaptation

**Experiment Design**

**Independent Variables**
- AG Level (feet) 0g; 1g; 1.4g
- Exercise workload 50W; 100W

**Dependent Variables**
- Cardiovascular system
  - Electrocardiography (EKG)
  - Blood pressure
  - Respiration rate
- Musculoskeletal system
  - Foot forces
  - Surface EMG sensors
  - Goniometers (knee & ankle)
- Motion sickness & comfort
  - Exit survey
  - Rating Perceived Exertion Scale

**Cardiovascular Modeling**
A lumped-parameter model will be developed to capture:
- Artificial Gravity - Hydrostatic pressure during centrifugation
- Exercise - Modeling strategy:
  - Arterial blood pressure set-point
  - Heart rate
  - Heart contractility
  - Arterial resistance (except leg)
  - Venous Tone
  - Leg arterial resistance (↑ leg blood flow)
  - Leg muscle pump (Prr leg compartment)
  - Intra-abdominal pressure (Prr abdominal compartments)

**References**