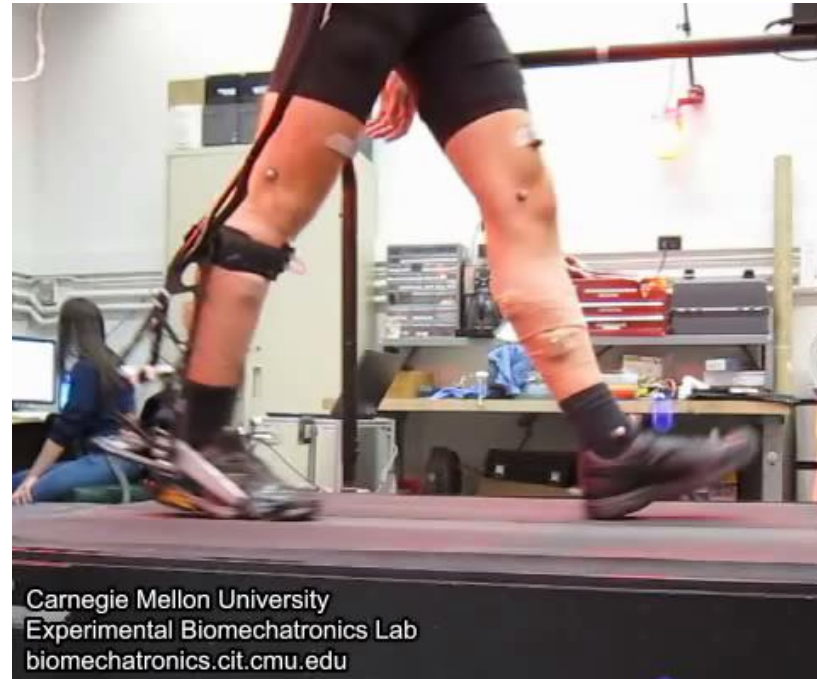
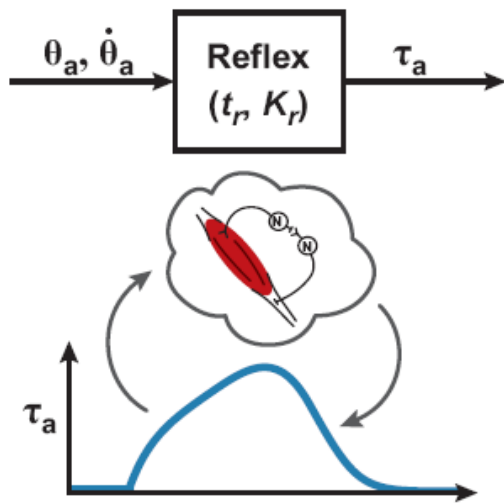


NSF National Robotics Initiative:

Rapid exploration of robotic ankle exoskeleton control strategies



PI: Steve Collins

Carnegie Mellon University

Experimental Biomechanics Laboratory

Project Overview

Missing keys for exoskeleton design:

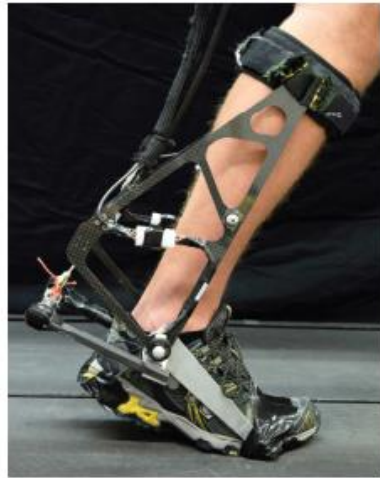
- Tools for rapid, systematic exploration
- Neuromechanics models of performance

Our approach:

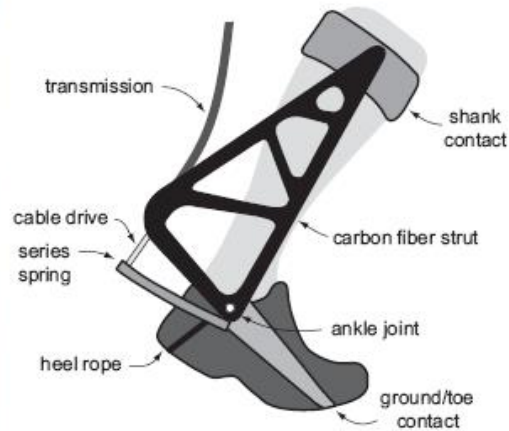
- Universal ankle-foot exoskeleton emulator
- Measures from muscle fascicle to whole body

Universal ankle-exoskeleton emulator

A Ankle exoskeleton



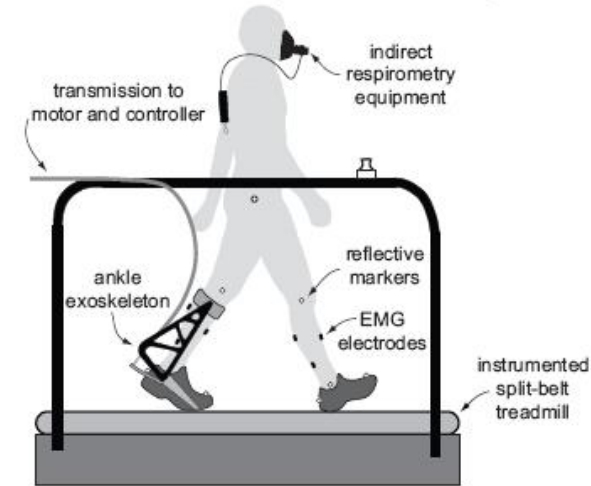
B Schematic of exoskeleton



C Experimental set-up

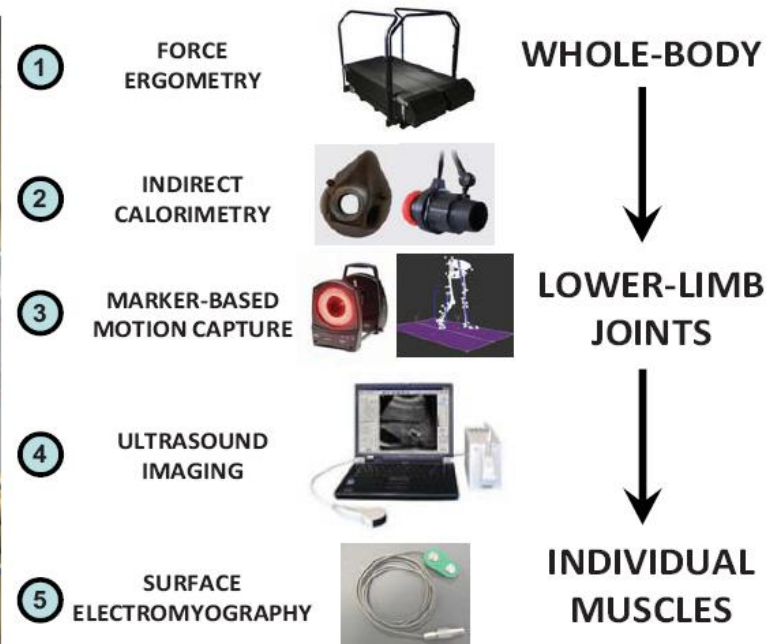
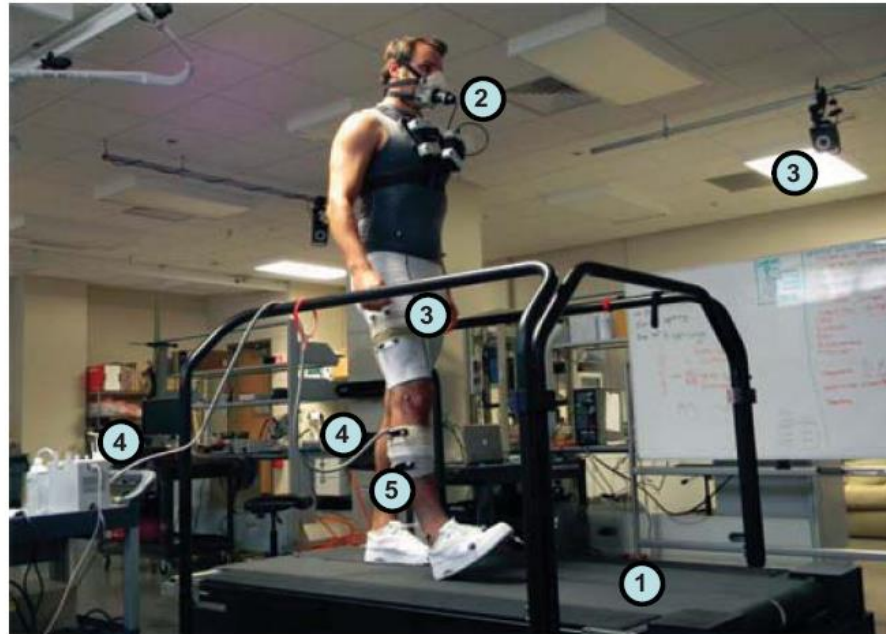


D Schematic of experimental set-up



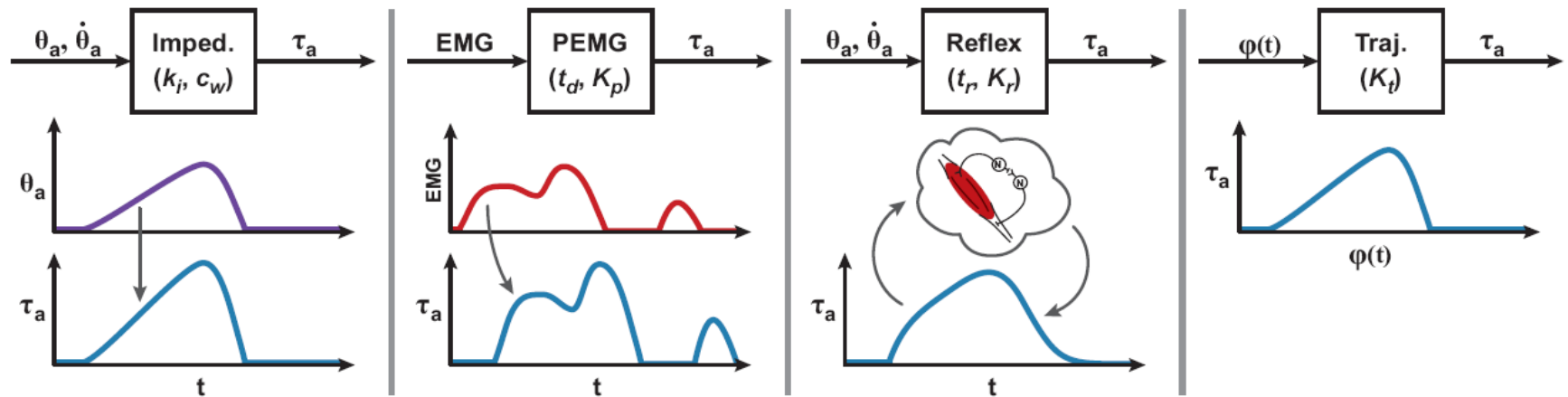
Trades autonomy for *exceptional* versatility.
From idea to experiment in hours, not years.

Multi-scale locomotion physiology toolset



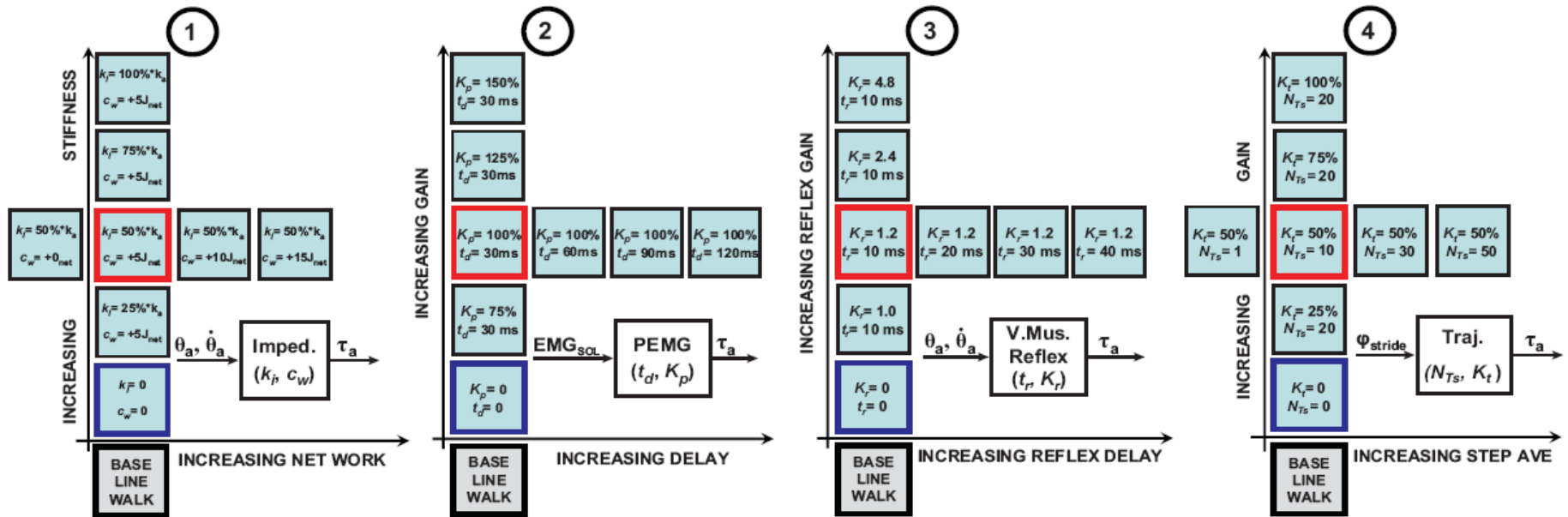
From whole-body dynamics and chemistry...
... to individual muscle mechanics and activation

Assistance strategies worth exploring



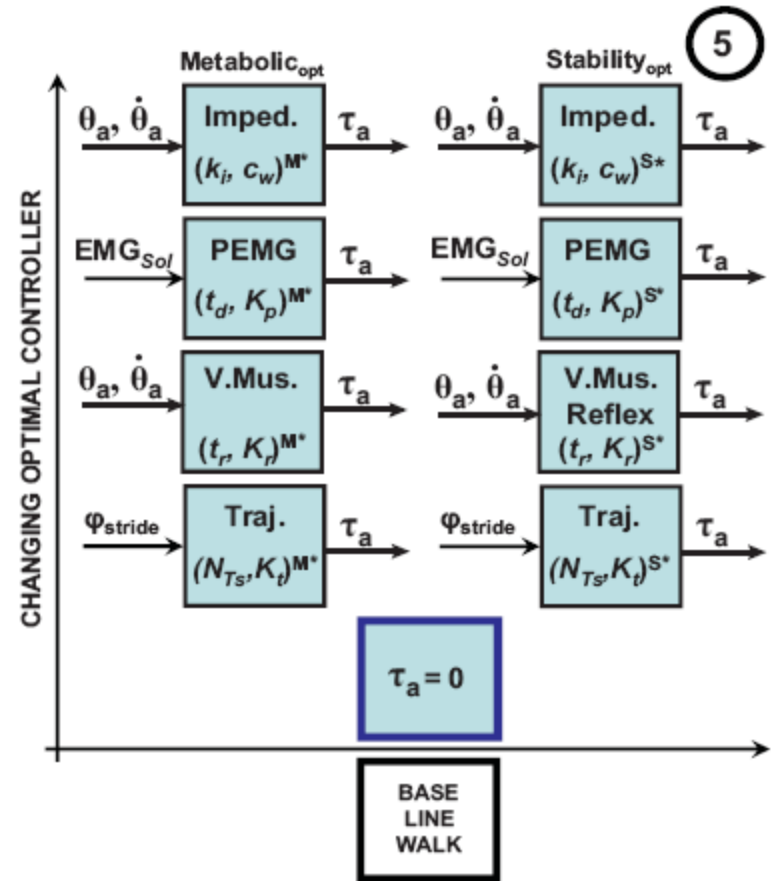
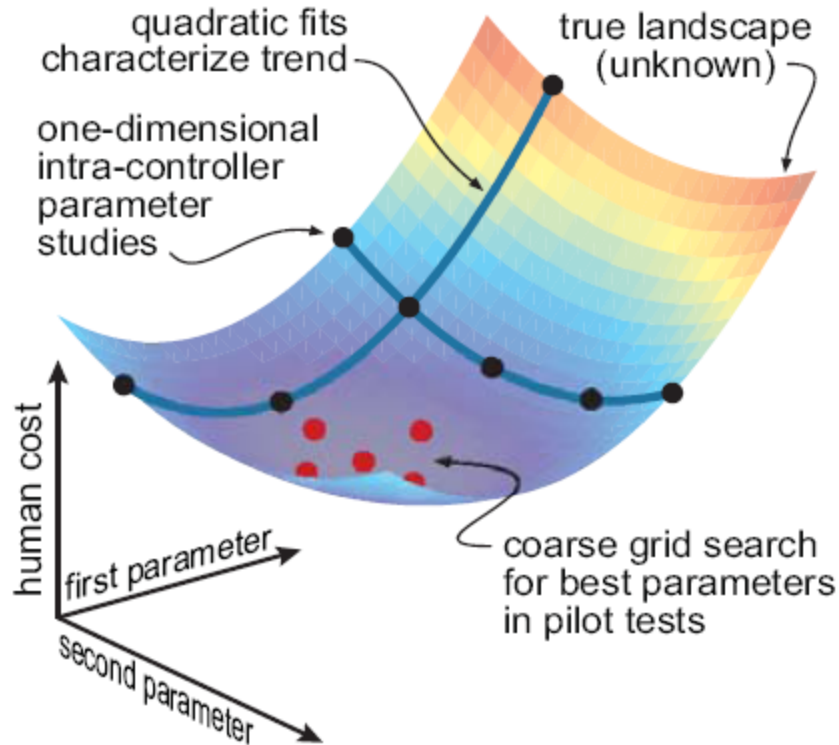
1. Impedance: springs and (negative) dampers
2. Proportional EMG: muscle amplifier
3. Reflex-like: virtual muscles and neurons
4. Trajectory-based: on the clock

Intra-controller experiments



Systematic exploration along key parameters

Inter-controller experiments



Comparison of each approach at its best

Milestones: Ahead of Schedule

Completed:

- Embodiment of all high-level controllers¹
- Parameter sweep on impedance control²
- Platform improvements and duplication³

In progress:

- Proportional EMG sweep (Q2, 2015)
- Online optimization (Q4, 2014)
- Expansion to knee (Q4, 2014)

1. Jackson and Collins (2014) In review: *Journal of Experimental Biology*

2. Zhang and Collins (2014) In review: *International Journal of Robotics Research*

3. Witte and Collins (2015) In preparation for *International Conference on Robotics and Automation*