Manipulation vs. Locomotion

NSF Workshop: Locomotion and Manipulation

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Boston Dynamics

Then and Now

- Juggling circa 1995
  - Hybrid controller selection to bring ball to rest (sequential composition)

- Spot robot "kick recovery" circa January 2015
 - Hybrid controller selection to bring the robot to a stand

Mobile Manipulation (motivation)

BostonDynamics

- Dynamic full body manipulation

  - Increased Workspace: 'Reach the top shelf'

  - Increased Strength: 'Lift with your legs'

  - Increased Velocity: 'Step into the throw'

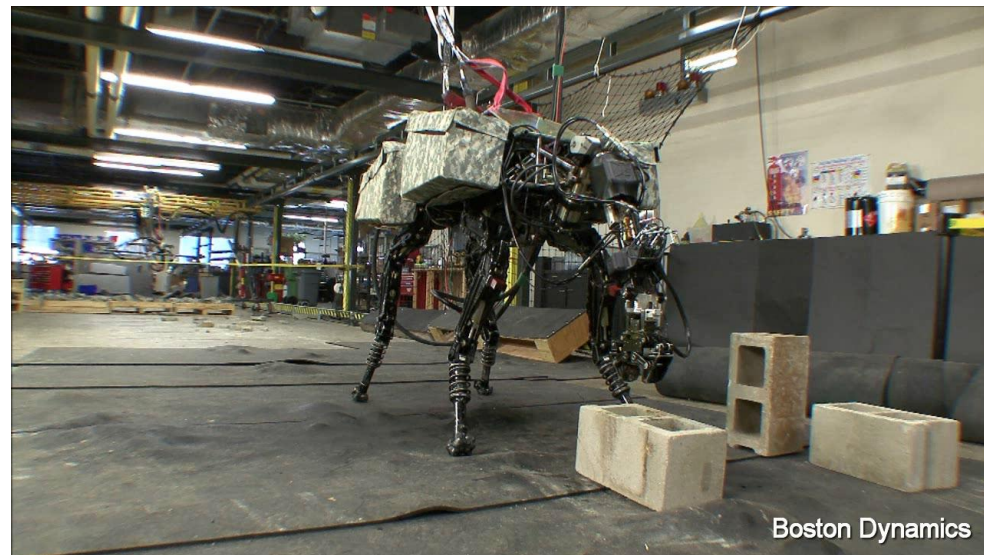- Requires coordinated motion of dynamic high DoF systems

Mobile Manipulation (example)

- Arm payload 6.8 Kg
- 16.5 Kg Dynamic lift

Boston Dynamics
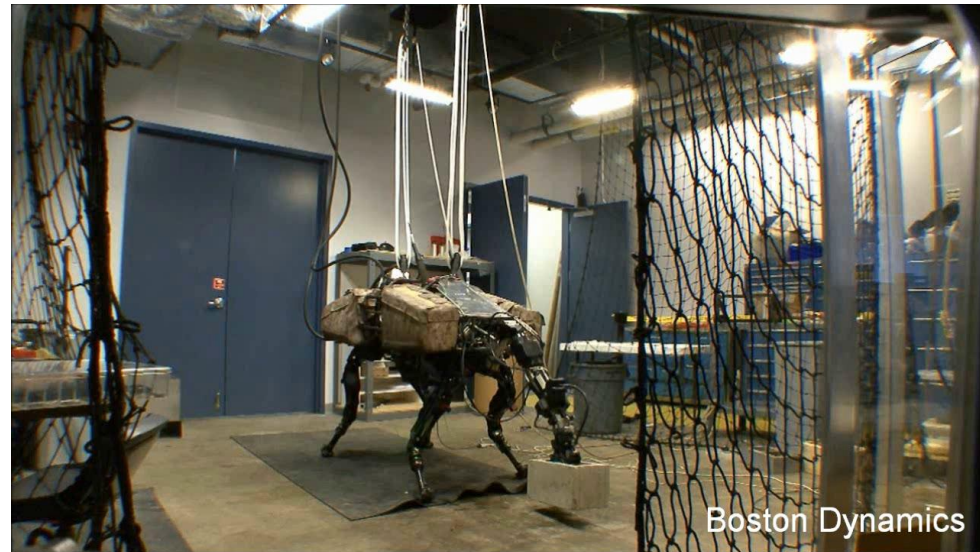
- "Arm" throw 2.9 m
- Full "body" throw 5 m
- Step into and recover after throw
- Arm-body-leg coord.

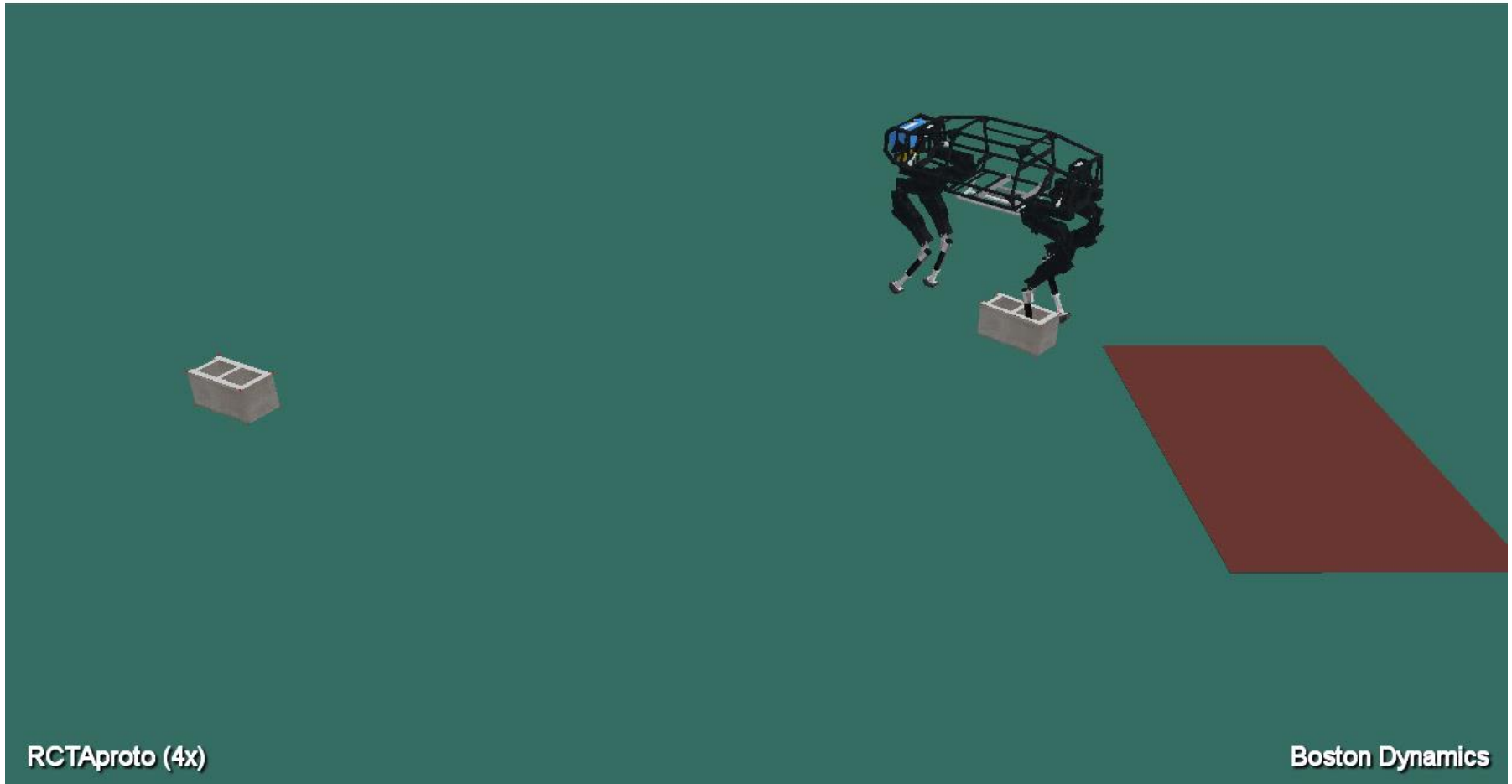
Boston Dynamics
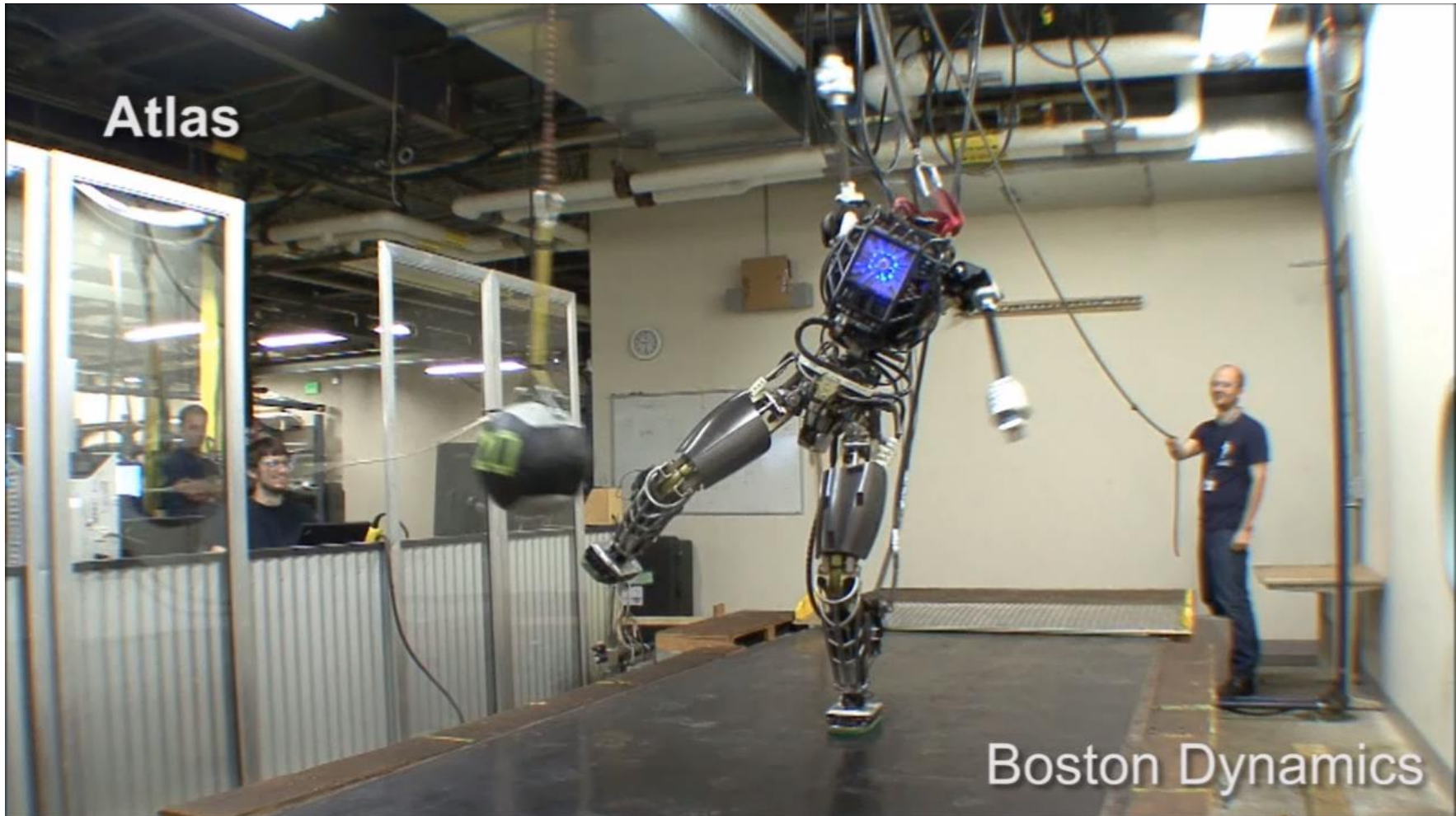
Manipulation vs. Locomotion

- Conjecture:
  The distinction is dynamics not kinematics
  - Both have plenty of non-holonomic constraints
  - Interesting when operating near performance limits
  - Dynamics and performance limits may not be dual
    - Inertia of arm/hand to payload vs. leg/wheel to body
    - Force constraints depend on kinematics and contact state
  - Other "inconsistencies"
    - Periodic vs. episodic behavior
    - Intermittent vs. continuous contact
- What about
  - Mobipulation, Full Body Dynamic Manipulation, Legipulation?

Legipulation?

- When is a leg an arm or a foot a hand?

RCTAproto (4x)

Boston Dynamics

Momentum Balance

Atlas

Boston Dynamics

- Is there a dual for this?

Behavior/Controller Composition
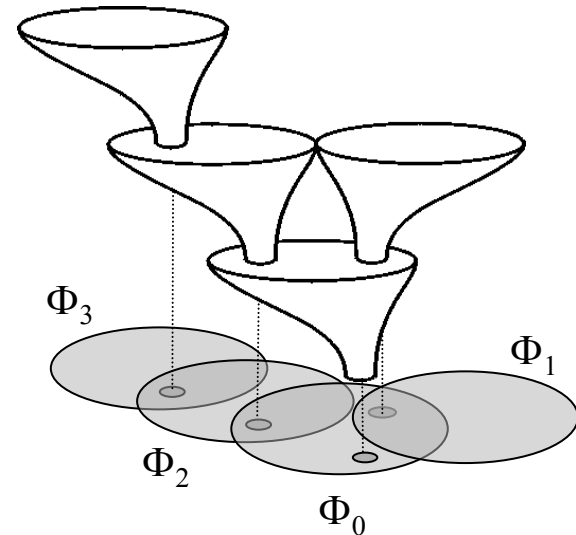
- Build complex behavior from many simple controllers

- State transitions based on estimates and measurements of system state

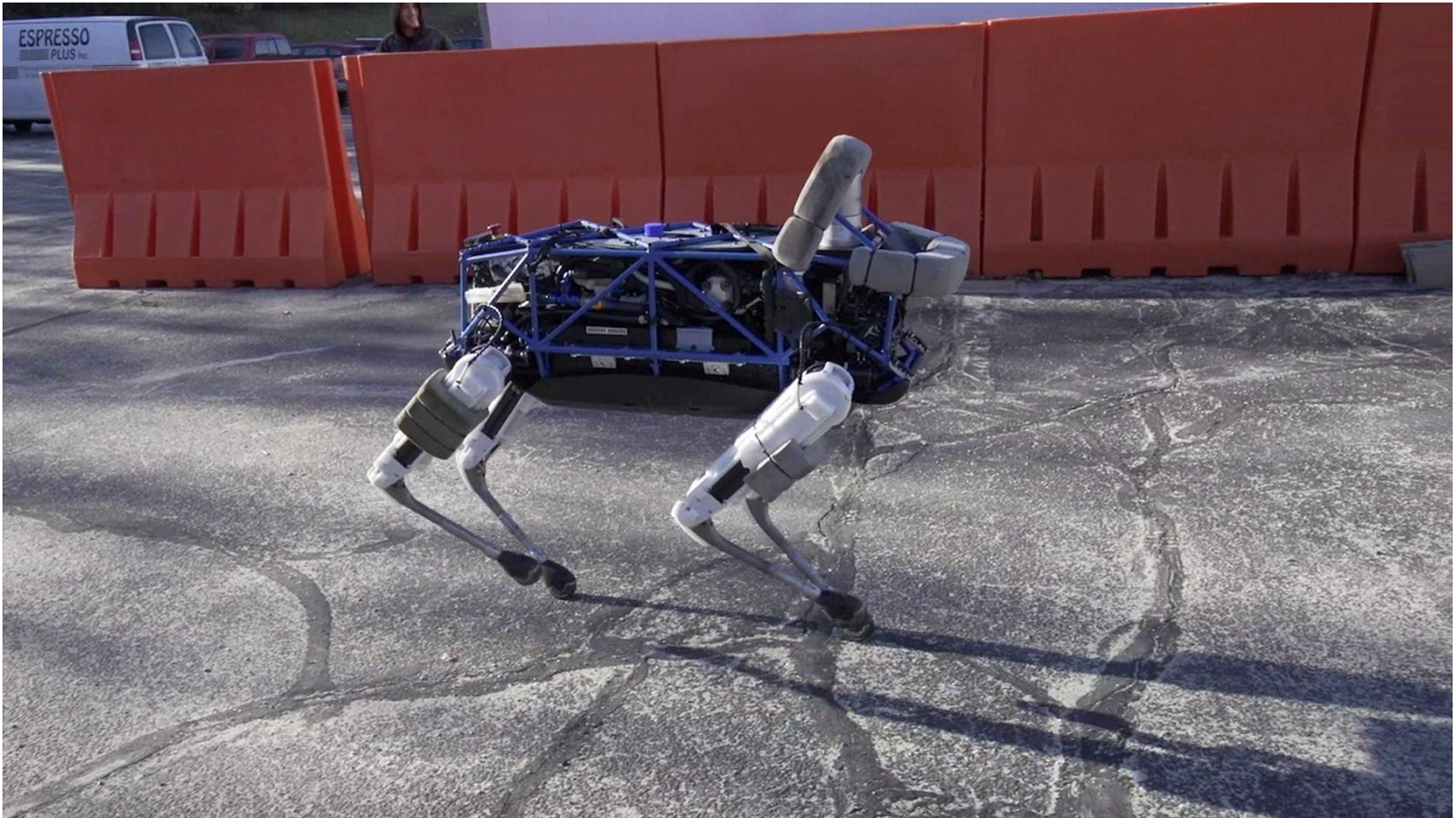- Sequential composition simplifies encoding complex behavior (improved robustness)

Behavior Transitions

- Automatic transition to a "catch" c. 1996
- Transition driven by ball state (position & velocity)

- Automatic transition to a "stair climbing" c. 2005
- Transition driven by contact state (position & force)

Behavior Transitions

- Operator cues desired behavior
- Transition depends on state estimates and contact state

Questions?