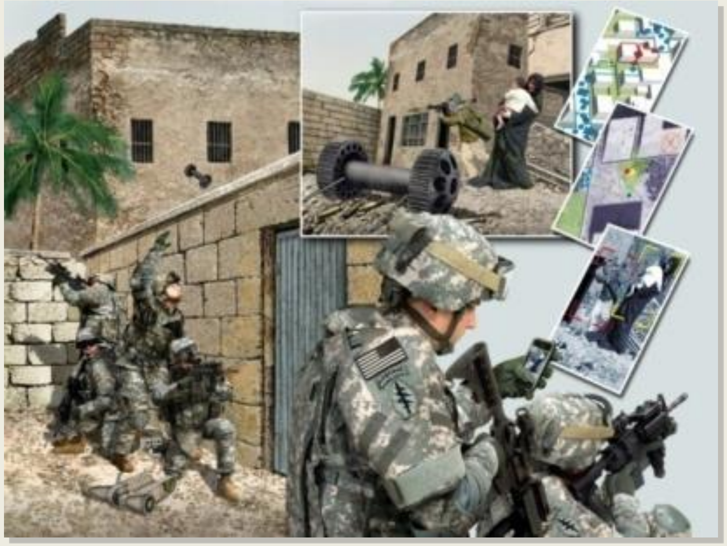
ARL Robotics Overview
Autonomous Systems Division

23 March 2017

Enable the teaming of intelligent systems with humans



Expand small unit sphere of influence - provide technology to enable:

- *Greater level of autonomy for heterogeneous systems:*
  - *Ground, air, & surface vehicles*
  - *From micro-systems to combat vehicles*
  - *From single units to swarms of devices*
- *Teaming capability*
  - *Increased intelligence, modular behaviors*
  - *Shared situational awareness & trust*

Focus on Army unique problem set

- *Dynamic, unstructured environments*
  - *Active opponent & non-combatants*
  - *Unknown & potentially hostile*
  - *High operational tempo*
- *Lack of similar commercial market*

RDECOM Director's Initiatives

"**Director's Initiatives.** The RDECOM Director has identified several high-risk, high-payoff initiatives, which are defined in Appendix E. Each will provide the Army with a revolutionary new capability and, together, constitute Future State Demonstrations. The initiatives are informed by the changing nature of the strategic environment, TRADOC's highest priority capability gaps, ASA(ALT)'s Top Challenges, and the potential to provide a leap-ahead capability for the Soldier. Each initiative draws upon a wide range of RDECOM core competencies that require an enterprise approach, thereby focusing multiple RDECs and ARL efforts on high-priority challenges for the future. The RDECOM Director's Initiatives are:

- Expeditionary self-sustaining base camp
- Long-range precision fires
- Counter unmanned aerial systems (UASs)
- **Robotic team member**
- Assured access to information"

Excerpt from "U.S. Army Research Development and Engineering Command Strategic Plan, Enabling Battlefield Dominance Through Technology — FY 2015 – FY 2040" page 14

"**Robotic team member:** Develop a robotic team member with the capability to provide logistics support, situational awareness, and direct and indirect fires for the small unit. This capability will include the ability to operate as a team member with minimal supervision by the Soldier. This will be accomplished through development and integration of novel mobility and manipulation technologies with sensors, fires, human-machine interface, and intelligent-processing technologies whose ultimate objective is to extend the situational awareness, survivability, and lethality of the Soldier and small unit."

Excerpt from "U.S. Army Research Development and Engineering Command Strategic Plan, Enabling Battlefield Dominance Through Technology — FY 2015 – FY 2040" page 40

Autonomous Systems Mobility and Manipulation Scope of Effort

What is Context of this Effort (Team/Individual, New/Ongoing/Concluding)?

This effort includes ARL internal research, Robotics Collaborative Technology Alliance (CTA), Micro Autonomous Systems Technology (MAST) CTA, and ARO sponsored research.

Robotics CTA: Carnegie Melon University, General Dynamics Land Systems, Florida State, Univ of Central Florida, Univ of Pennsylvania, Qinetiq North America, Cal Tech/Jet Propulsion Lab

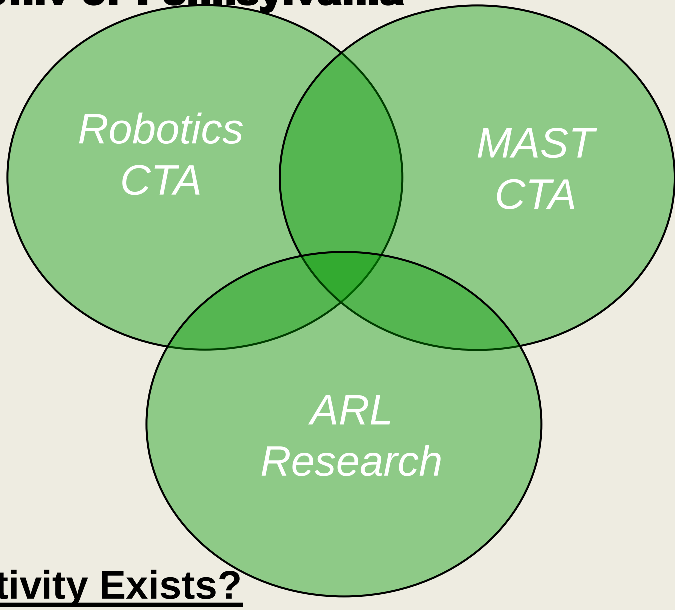
MAST CTA: Univ of Maryland, Univ of California Berkley, Univ of Pennsylvania ,North Carolina A&T, Harvard, Cal Tech, Poli Milano.

ARO: Complex Dynamics and Systems and other projects

ARL Internal Research: HRED, SEDD, VTD, WMRD

Pursuing collaboration with DARPA

ARL sponsors wide-ranging collaborative research conducted internally and with our collaborators (CTAs, MURIs, single investigator programs)



Scientific Foundations: What ARO or Other Academic Connectivity Exists?

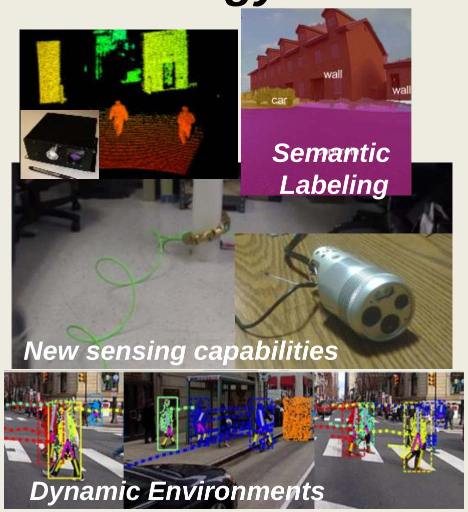
•Most of the researchers have significant contributions to the relevant fields of mobility and manipulation including receiving relevant funding through ARO, AFOSR, DARPA, etc.

Are there related efforts or connectivity to other ARL Directorates/DoD Agencies/others?

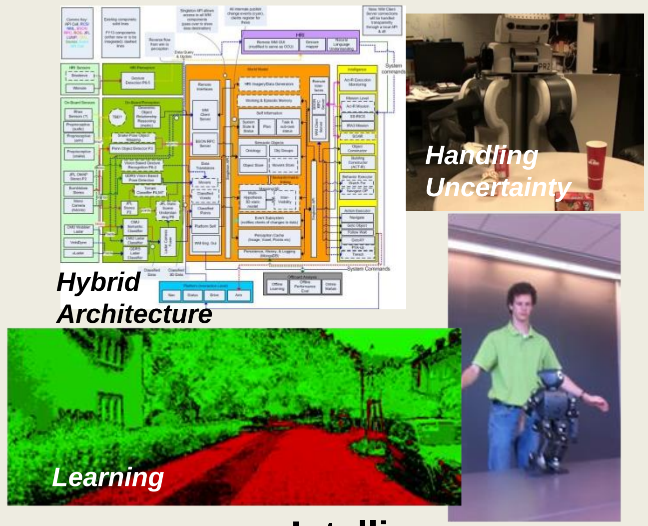
•Annual review of this program invites the participation of government organizations including all of ARL, many of the RDECs, NRL, AFRL, & DARPA

Robotics Collaborative Technology Alliance

Technology to Enable Teaming of Soldiers and Robots for Small Unit Operations

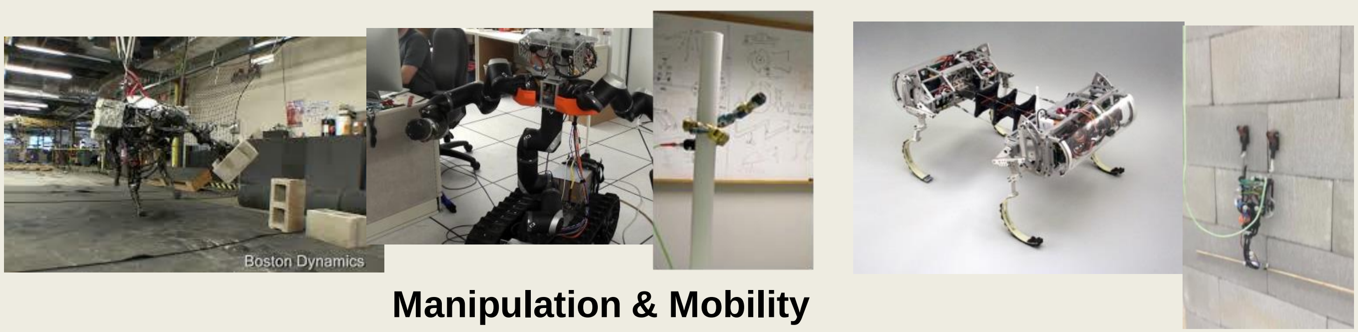


Perception
Understand the Environment



Intelligence
Reason, Learn, Plan, & Act

Human-Robot Interaction
Common view, Transparency, & Trust



Manipulation & Mobility
Manipulate objects with near-human dexterity & maneuver in 3-D environments

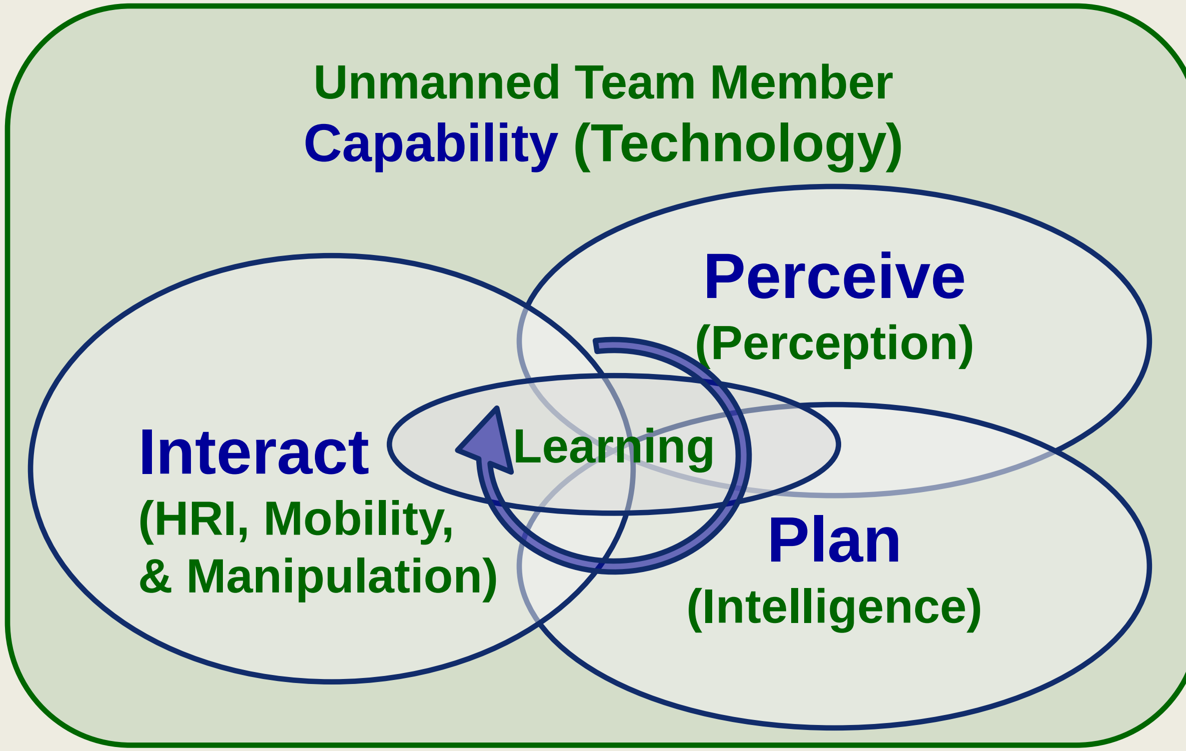
ARL | California Institute of Technology Jet Propulsion Lab | Carnegie Mellon | General Dynamics Robotic Systems | QinetiQ North America | UCF | Penn

RCTA Technologies

Making unmanned systems an integral part of the small unit team

Systems that:

- ***Understand the environment***
- ***Learn from experience***
- ***Adapt to dynamic situations***
- ***Possess a common world view***
- ***Communicate naturally***
- ***Conduct useful activity***
- ***Can act independently, but within well prescribed bounds***



Sciences for Maneuver Campaign Multi-modal Mobility and Manipulation

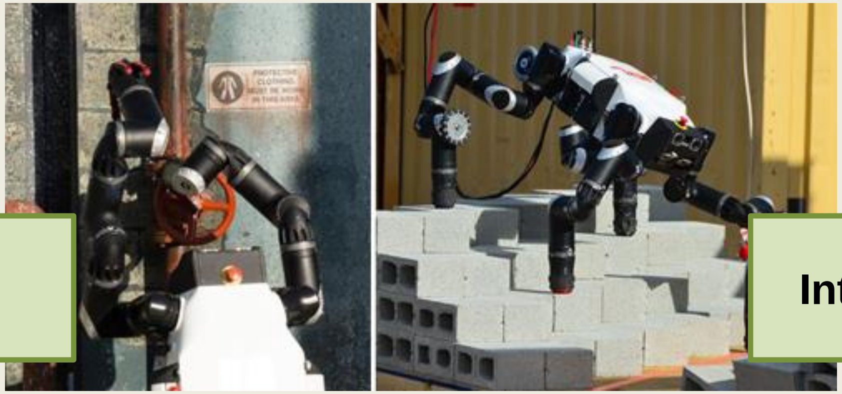
PLATFORM MECHANICS: Fundamental research to enable highly-maneuverable high-speed air and ground vehicle platforms and subsystems for the future Army, ranging from large combat/cargo vehicles to micro-scale devices.

Fluids, Structures & Dynamics

Actuation and Mechanisms

Platform Configuration Concepts

JPL RoboSimian



Perception

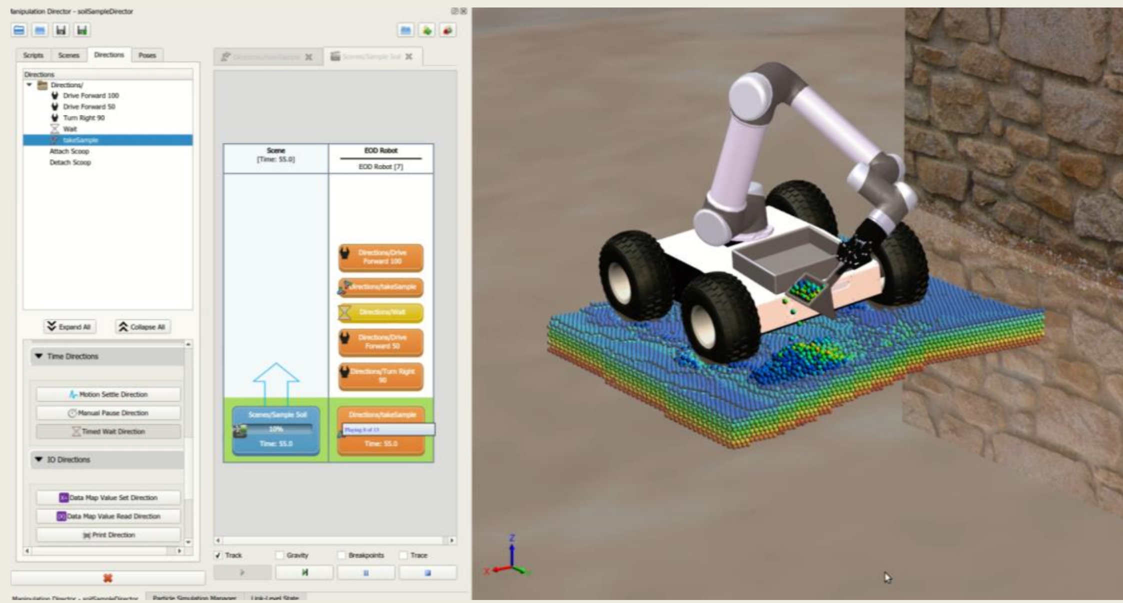
Intelligence & Control

VEHICLE INTELLIGENCE: Focus on fundamental research to enable effective teaming of Soldiers and unmanned vehicles to conduct maneuver and military missions. Centered on enhancing autonomous capabilities of unmanned / intelligent systems in real world environments.

Human-Friendly Robotic Programming

SBIR:
Advanced Programming and Teaching Interfaces for Autonomous System Control

Boston Dynamics Big Dog with Manipulator



Robot Programming with Real-Time Particle Simulation

Objective: **Develop interface(s) to allow Soldiers to "teach" or program robotic manipulation and mobility through virtual simulation and through real-world demonstration (no need to write text-based code) which the robot can apply autonomously in various situations.**

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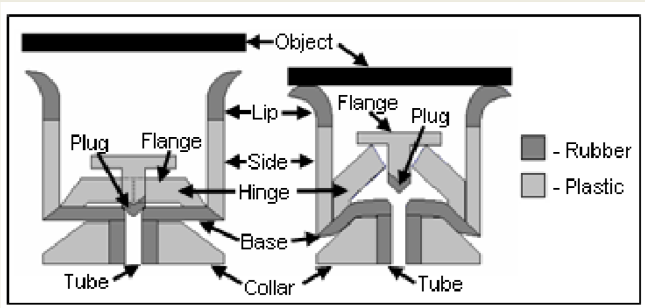
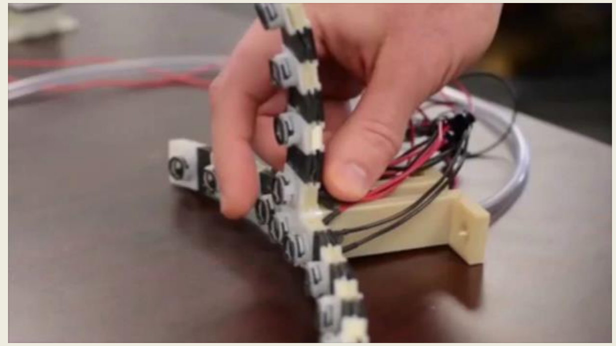
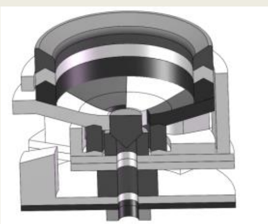
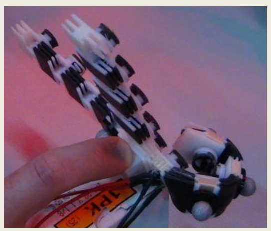
Robust Passive Grasping

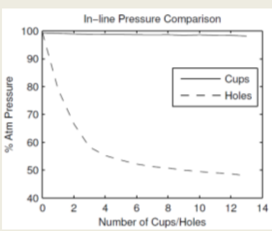
Results

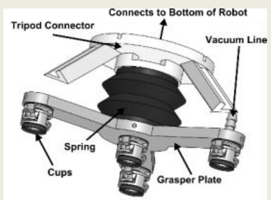


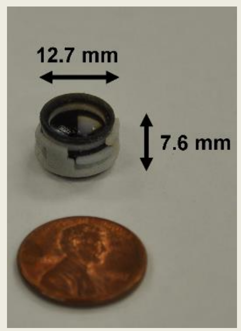


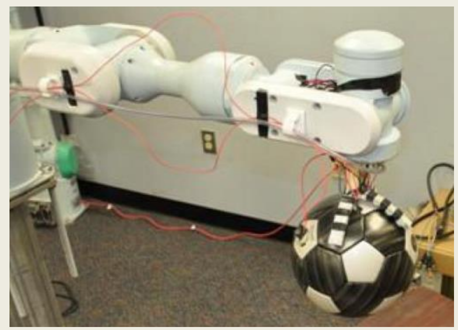


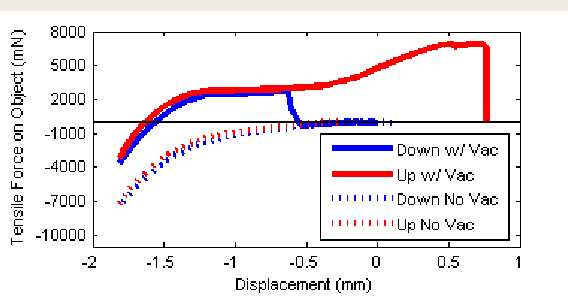












Versatile Aerial Grasping Using Self-Sealing Suction

Chad C. Kessens, Justin Thomas,
Vijay Kumar, and Jaydev P. Desai

RAMS Laboratory
Robotics, Automation, and Medical Systems Lab
RDECOM
ARL US Army Research Laboratory
Penn Engineering
GRASP LABORATORY
General Robotics, Automation, Sensing & Perception Lab

Objectives

- Expand the range of object shapes and sizes able to be grasped by robot
- Expand range of perching locations for aerial vehicles
- Simplify grasping methods and understand impact on grasp stability and quality
- Enable generation of large lateral forces by aerial vehicles to perform work in supersurface

Methods

- Utilize local pulling contact forces to eliminate necessity of opposing contact force
- Passive self-sealing design for scalability
- Leverage environmental forces for activation to reduce cognitive and perception burdens

Accomplishments

- Designed, developed, and patented self-sealing suction technology for scalable pulling force
- Developed SMA-actuated hand with 13 cups and compliant planar hand for aerial grasping
- Characterized cup performance and capability to develop 6 DoF contact model
- Demonstrated ground-based and aerial robotic grasping of wide range of object shapes/sizes

Present Work

- Applying grasp stability theory to formation of quality grasps
- Investigating robustness to object geometry and contact points
- Developing compliant hand on which to mount cups for grasping range of curved objects

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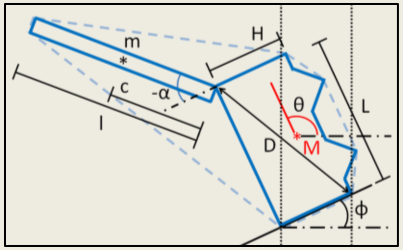
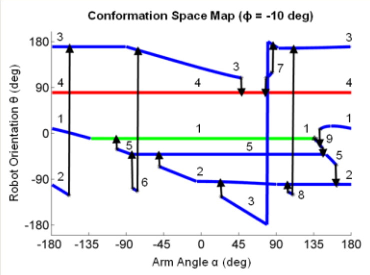
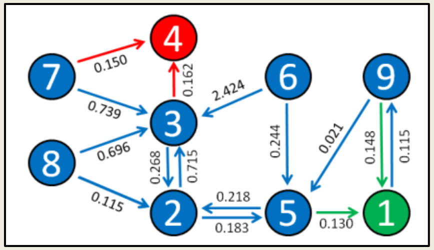
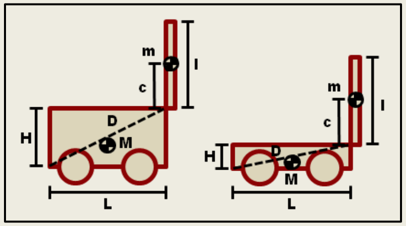
Self-Righting a Generic Robot

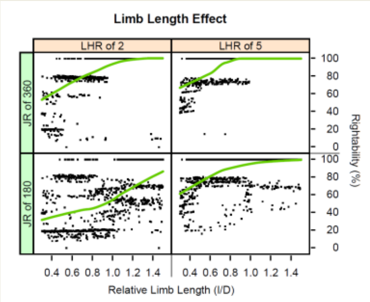
Results

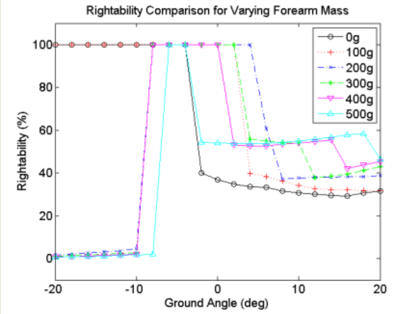


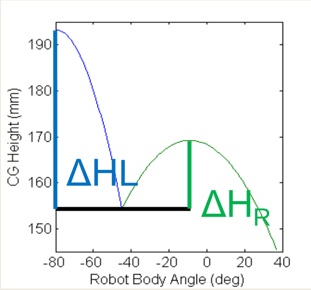


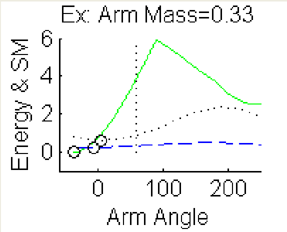


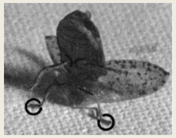


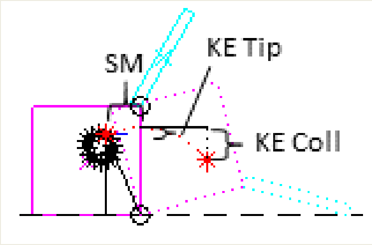


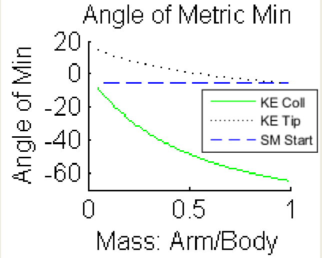












Objectives

- Enable efficient, real-time path plans for self-righting of a generic (resource limited) robot
- Evaluate ability to self-right under various conditions to inform acquisition decisions
- Understand relationship between morphology and ability to self-right to improve design

Methods

- A priori analysis of state space map to identify high level paths through joint space
- Determine % of starting states that are unable to reach the goal under various conditions

Accomplishments

- Developed analysis framework condensing state space map to simple directed graph
- Demonstrated use of self-righting metric for appendage mass tuning on 3-DoF robot
- Leveraged framework to identify unknown ground angles to within < 1 degree
- Demonstrated self-righting of an Army fielded vehicle used for EOD missions
- Utilized framework to analyze role of wing shape in animal self-righting
- Demonstrated use of inertial appendage methods for self-righting dynamically
- Applied adaptive sampling methods to analyze righting of an 8 DoF system

Present Work

- Extending analysis to 3D
- Analyzing dynamic pushing methods
- Applying torque limitations

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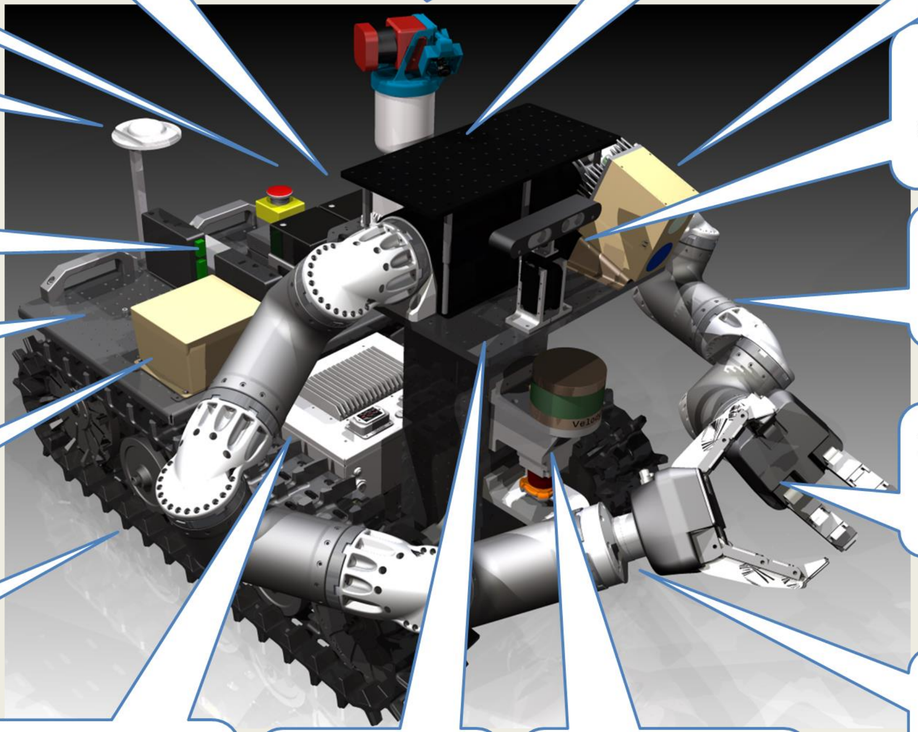
Robotics Collaborative Technology Alliance Research Platform

Non-ITAR - Robotic Manipulation Platform (RoMan)



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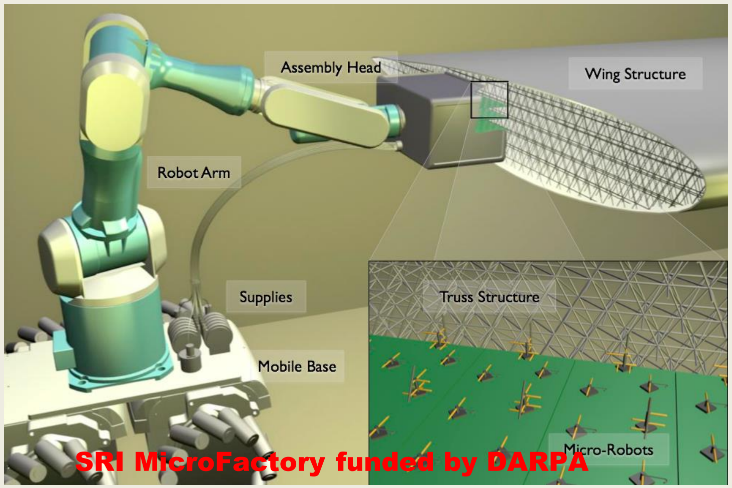
Next Gen Fabrication and Robotics

Designing and building intelligent, networked, and actuated structures particle by particle:

Robots to Build Gen-After-Next Machines

- It will require a new paradigm in robotic fabrication to build systems employing active structures.
- MicroFactories (SRI funded by DARPA), next-gen 3-D printing, and hybrids of the two are candidate fabrication technologies.

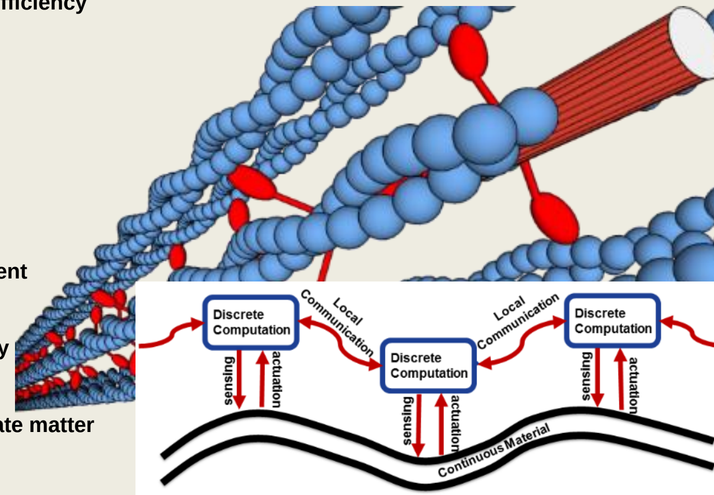


Active Structures Topics

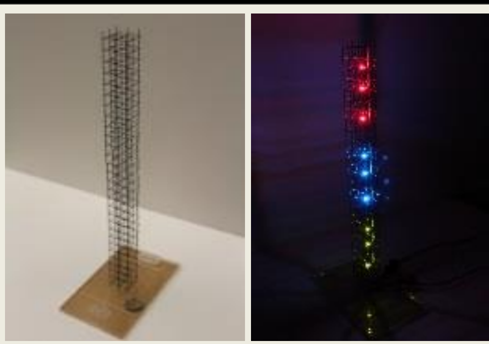
- Nano to macro scale fabrication and integration
- Emulation of muscle functionality and efficiency
- Emulation of capabilities similar to skin
- Lighter stronger structures
- Adaptive structures
- Self monitoring structures
- Computation for distributed sensing
- Computation for distributed actuation
- Automated structural damage assessment
- Vascularized organic tissue fabrication
- Physical human to machine connectivity
- Highly capable and efficient robots
- Massively parallel assembly of particulate matter

Biomimetic Structures

- Inorganic structures with organic functions
- Develop actuation inspired by nature

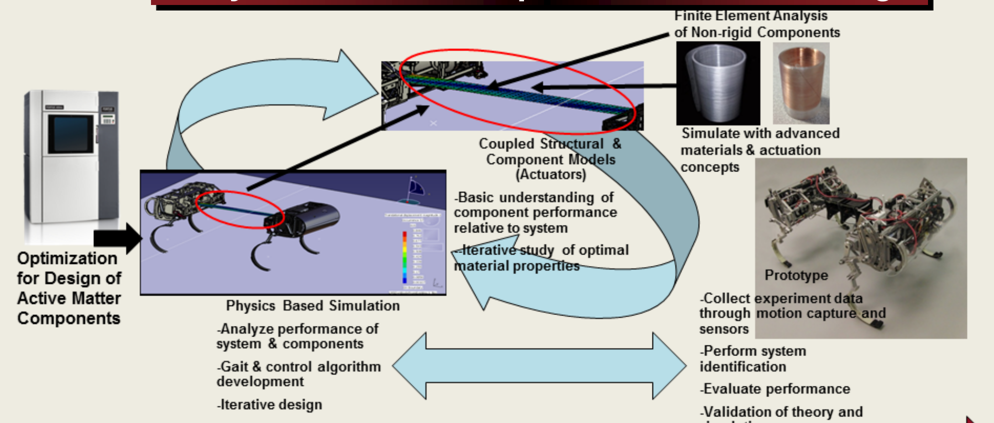


New Fabrication Capabilities



Embedded Electronics in Structures

Physics Based Component Level Modeling

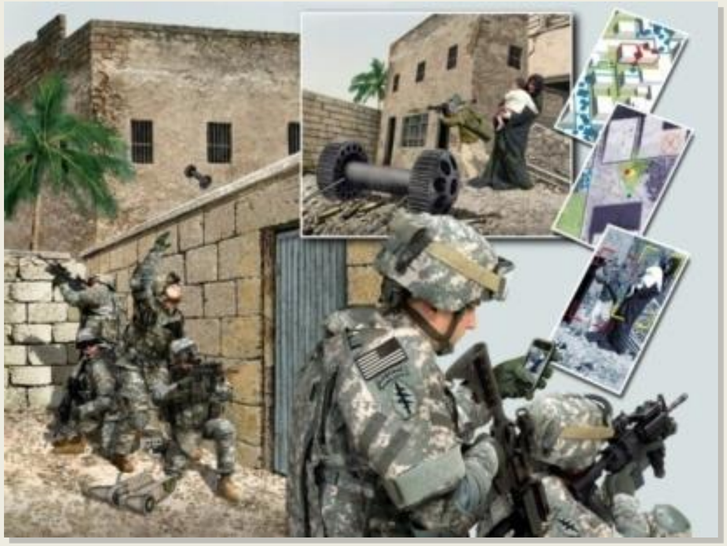


Theory → Design by Mission Spec → Simulation → Evolve Design, Components and Algorithms; Validation → Transition Evolved Technologies

The Nation's Premier Laboratory for Land Forces

Heterogeneous Teams of Humans and Intelligent Machines

Vehicle Intelligence



Solution through human-robot collaboration

Technology Focus

- **Perception**
- **Learning & reasoning**
- **Human-machine interaction**
- **Interaction with the physical environment**

Purpose:

- Enable effective teaming of humans and machines to resolve conflicts and provide relief in air, ground, and maritime environments

Products:

Underpinning science to enable:

- Fine grained understanding of situations, social cues, behaviors, and physical environment to support learning, reasoning, and behavior.
- Adaptive learning employing compact representations, adaptive on-line, "on-the-fly," interactive learning, for rapid reasoning, pattern recognition, dynamic locomotion, and manipulation.
- Effective, intuitive, bi-directional communication between humans and machines
- Interaction with complex 3-D environments to permit human scale and speed mobile manipulation & locomotion, understanding and movement through 3-D environments.

Payoff:

- Expanding the capabilities of humans to resolve problems through effective and efficient teaming with machines using natural dialog to communicate and minimizing the need for fine grained control of physical and software agents.

The End

QUESTIONS ?