U.S. Army Research, Development and Engineering Command

Micro Autonomous Systems and Technology CTA

ARL

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Brett Piekarski
MAST CTA CAM
Branch Chief, Micro & Nano Materials & Devices
U.S. Army Research Laboratory

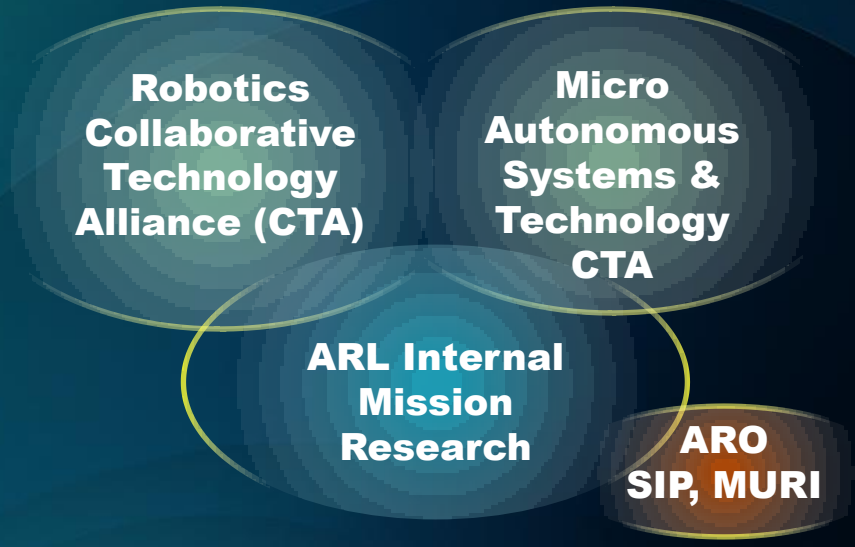
ARL Autonomous Systems Research Enterprise

Enable the teaming of autonomous systems with soldiers

Soldiers/Unmanned System Teaming:

- Combat multiplier
- Team member
- Heterogeneous groups
- Following commander's intent

Provide fundamental science underpinnings of autonomous systems for the Army



From micro-systems to combat vehicles

Supervised Autonomous Assets for the Dismount

To provide rapid and mobile ISR and mission support for the Dismounted Soldier beyond the eye of current national assets

Caves and Strategic Bunkers

Jungles and Under Canopies

In Urban and Rubble Environments

Challenges to Achieve Vision

Military Relevant Missions:

- Soldier ISR Asset for Rapid and Mobile Deployment - payloads
- Constantly changing environments and objectives – learning
- Small Heterogeneous teams
  - Semi-autonomous systems
  - Human in the loop
  - Intelligent Systems/Assets

Military Relevant Environments:

- Highly Unstructured to Austere
- Limited to no a priori knowledge
- GPS denied and Low/no Light
- Complex RF environments
- Dynamic and Hostile

Technical Challenges:

- Robust operation across domains
  - Caves, Jungle, Urban, etc
- High Operational Tempo
- Soldier transportable systems
  - SWaP constrained
  - Processing constrained
  - Gust tolerant & Low Re flight
  - Complex terrain ground mobility
  - Fast vehicle dynamics and poor models
- Localization in Austere environments
- Long Duration GPS denied navigation
- Minimalistic Mapping
- Communications

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Microautonomous Systems and Technology

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Enhance tactical situational awareness in urban and complex terrain by enabling the autonomous operation of a collaborative ensemble of multifunctional, mobile microsystems

Rapid and Mobile ISR for the Dismounted Soldier

MAST CTA

- 6.1 Basic Research Program
  - funded by cooperative agreement
    - ~$7.5M per year
  - 5 year initial program awarded in Feb 08
    - Option for 5-year extension awarded – Nov 2012 Start

- 6.2 Technology transition
  - Unfunded - indefinite duration-indefinite quantity (IDIQ) task order contract
    - Current funded efforts from
      - DARPA
      - Corps of Engineers
      - DTRA
      - Navy

MAST CTA Organization

Four Research Centers:

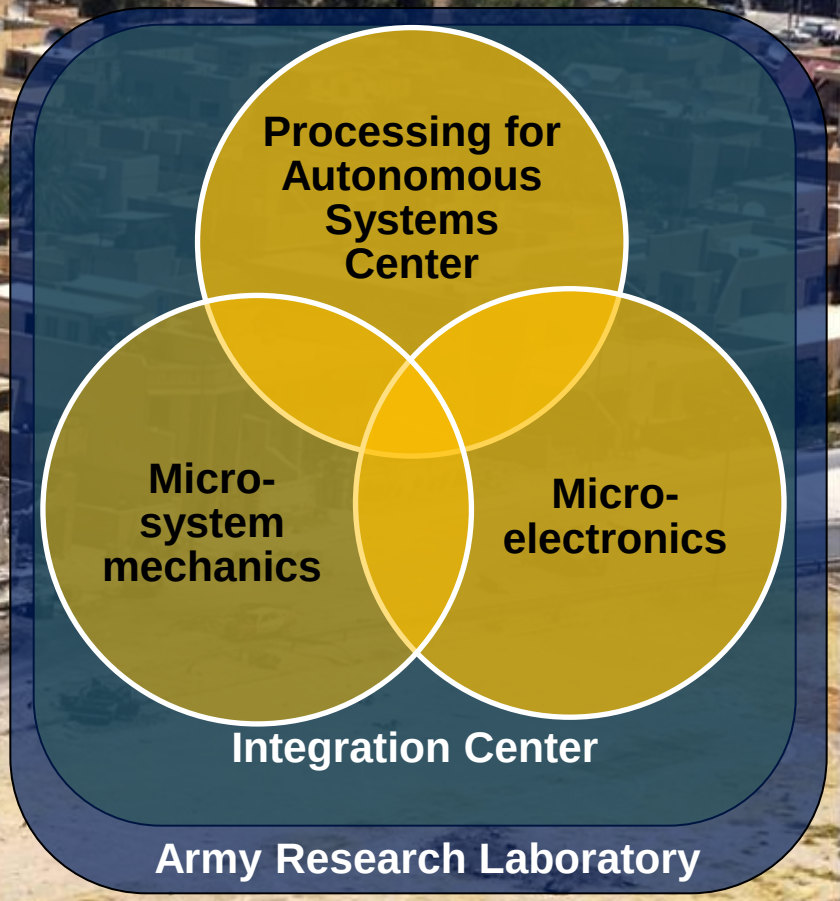
- Integration - BAE/JPL
- Microsystem Mechanics – Maryland
- Microelectronics – Michigan
- Autonomous Operation – Pennsylvania

General Members and Subawardees:

Georgia Tech, Harvard, Stanford, MIT, UC Berkeley, CMU, Univ. of Washington, New Mexico State, Univ. of New Mexico, UT Austin, Univ. of Delaware, Drexel, VT, UC Merced, KMEL Robotics, Daedalus Flight Systems

Four Cross-Cutting Research Thrust Areas:

- Mobility, Control, and Energetics
- Communication, Navigation, and Coordination
- Sensing, Perception, and Processing
- Joint Experimentation



Technical Management Group (TMG)

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Navigation and Control of Collaborative MicroSystems

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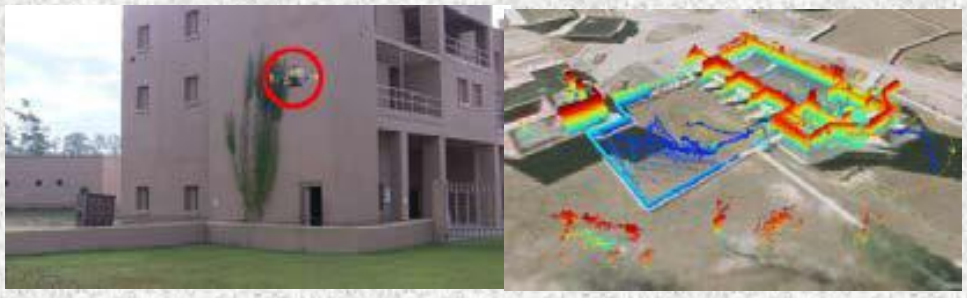
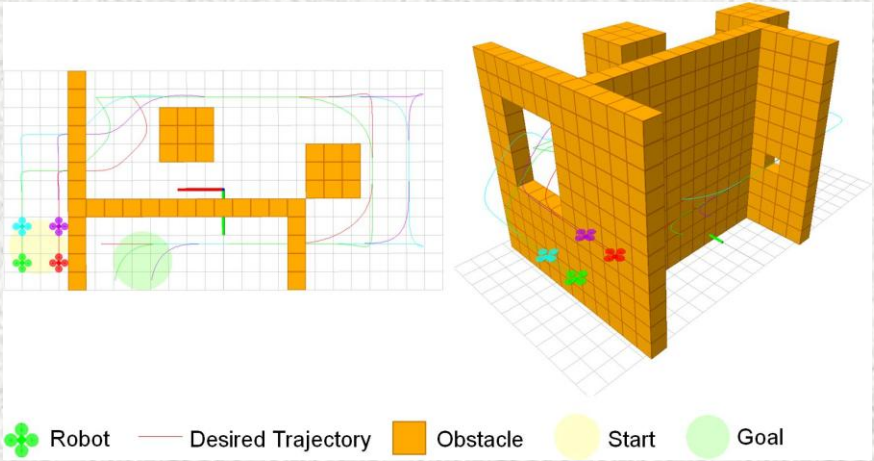
Penn Carnegie Mellon University ARL

Indoor/Outdoor GPS Denied Navigation and Mapping



Real-time motion generation for groups of micro-UAVs operating in cluttered, partially-known environments



Heterogeneous Collaborative Systems

Aggressive Maneuvers and Collaborative Behaviors

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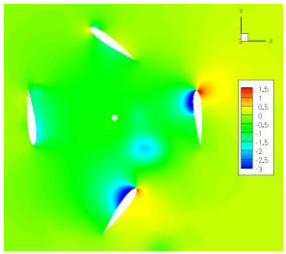
Penn

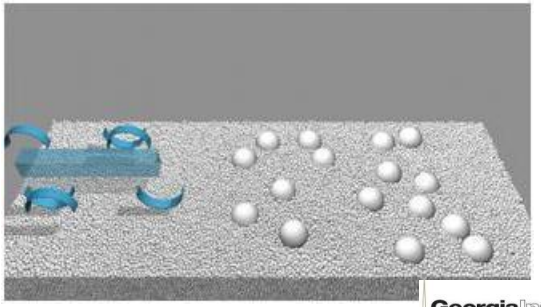
Penn

Aeromechanics and Terramechanics

Novel Systems - Cyclocopter

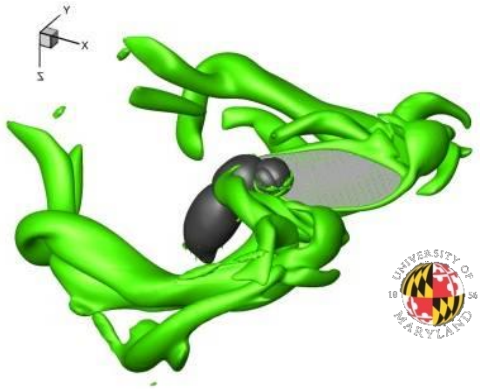


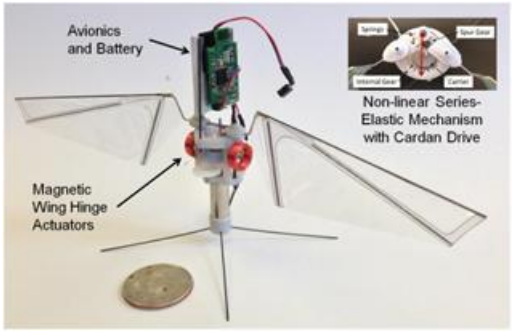
Understanding Ambulation over Complex Terrain



Georgia Institute of Technology

CFD, PIV, etc tools and understanding flapping flight





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Bio-Inspired Agility and Control

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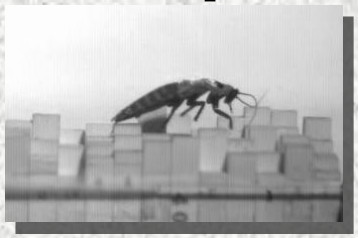
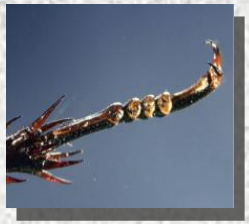
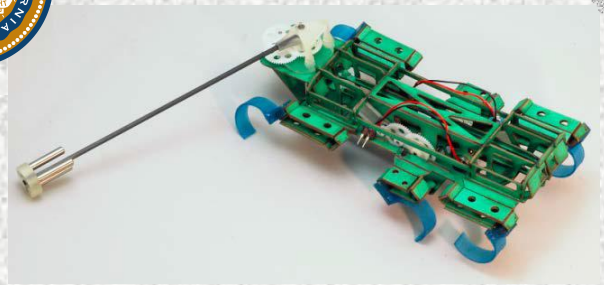
Ambulation and Transitions in Complex Terrain





Use of Tails and Appendages



Perching and Grasping

Penn

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Sensors for Micro Autonomous Systems

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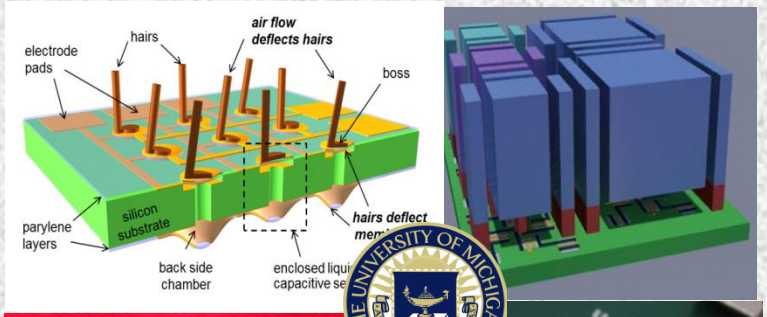
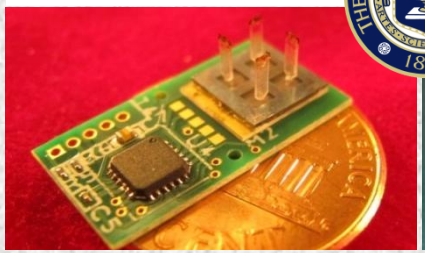
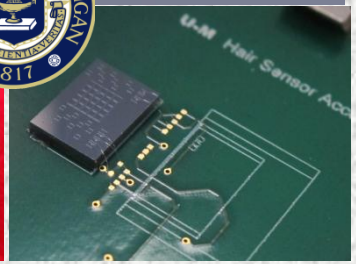
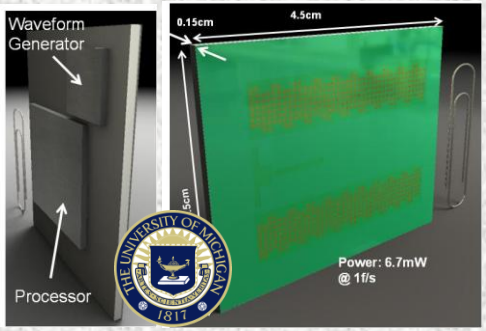


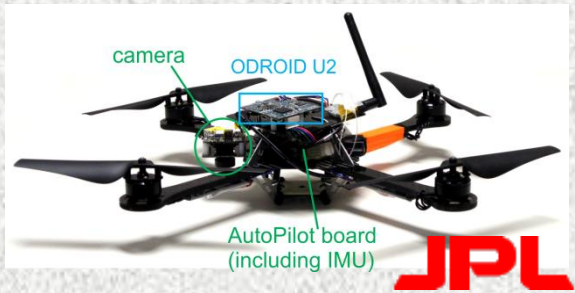




Hair-like Arrayed Sensors for Gust and Acceleration Sensing



5g 220 GHz Radar



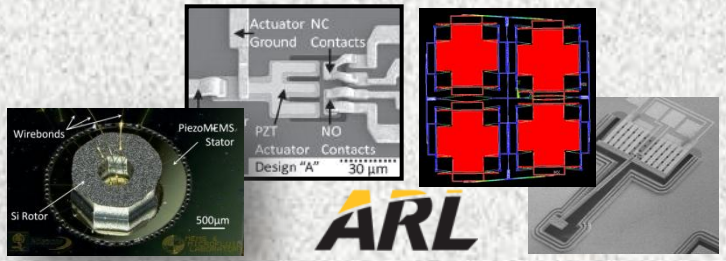
Fail-safe State Estimation Using Visual and Inertial Sensors

Small Antennas for Low VHF Comms

Stereo/Optic Flow Sensor Fusion in Inverse Depth Space

Penn Carnegie Mellon University

Robust State Estimation



PiezoMEMS Enables PNT Solutions

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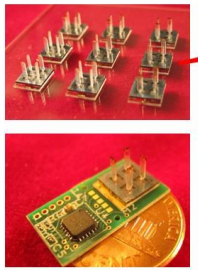
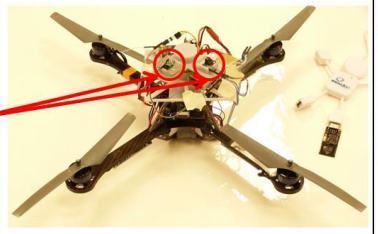
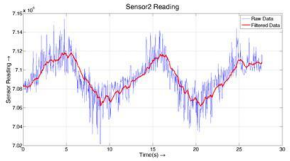
Joint Experimentation Thrust

Fabrication of next-generation sensors and new readout/interface PCBs

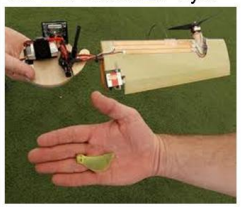


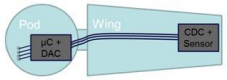
Preliminary 2-D directional sensing using two HAIR sensors integrated on UMD Quadrotor





Two PCB design/fab for LM Samarai flyer

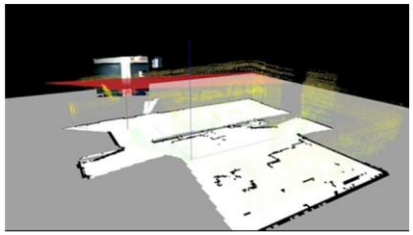


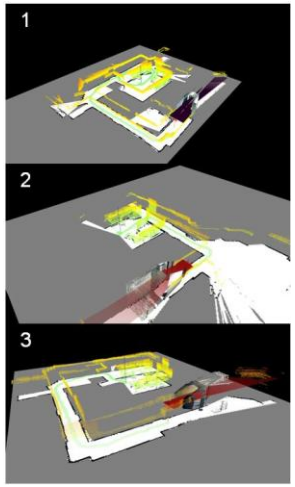


Wind/Gust Sensing and Mitigation on MAST-Scale MAVs

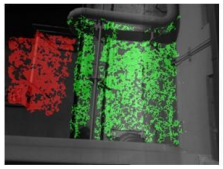
Dataset Collection:

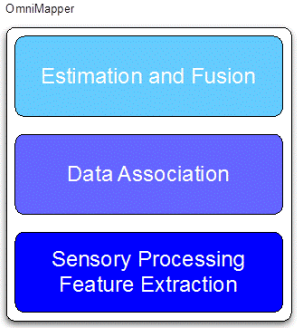
- Multiple data sets collected:
  - Measurements from multiple sensors
  - Consistent environment and starting point (for comparative benchmarking)
  - Preliminary environments exhibit small loops

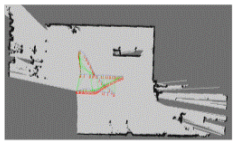


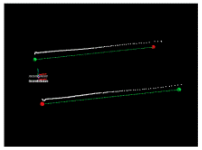


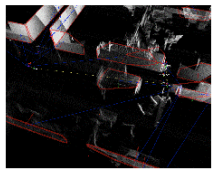
Active Cooperative Mapping by MAVs

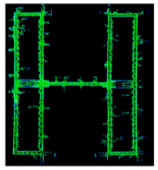




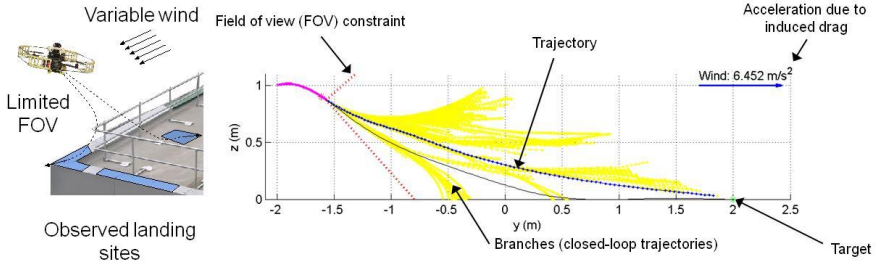








Heterogeneous Robot Teams for Mapping 3-D Indoor Environments



Autonomous Rooftop Landing for Surveillance and Payload Drop-Off

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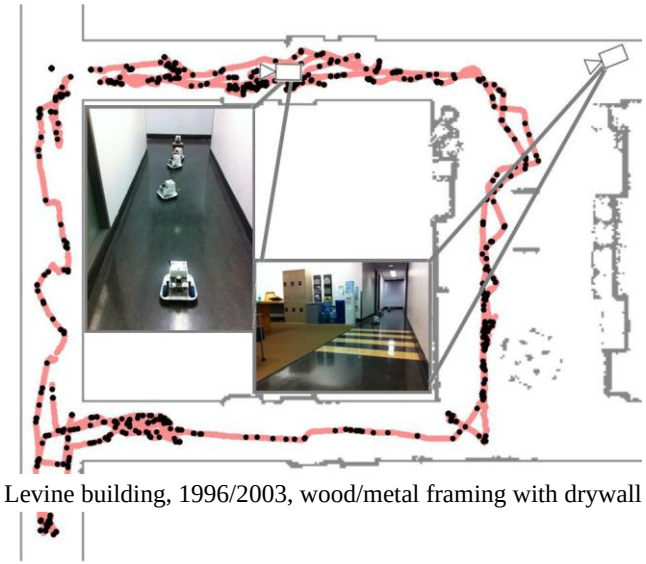
Collaborations and Transitions with ARL

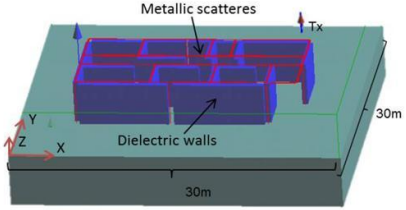


Levine building, 1996/2003, wood/metal framing with drywall

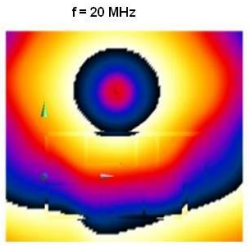
Autonomous Navigation for Communication Maintenance

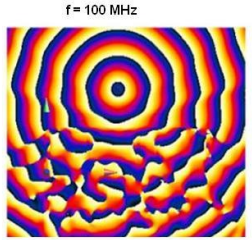
Fikadu Dagefu (ARL), Prof. Kamal Sarabandi (UMICH)

20 MHz Antenna
(New version 1in^3)
< λ/200



Indoor / Outdoor Simulation Scene

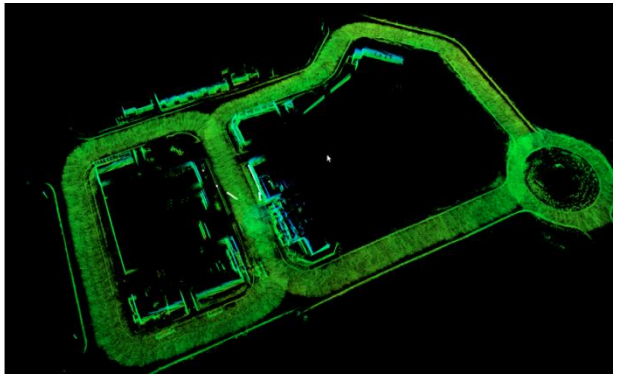




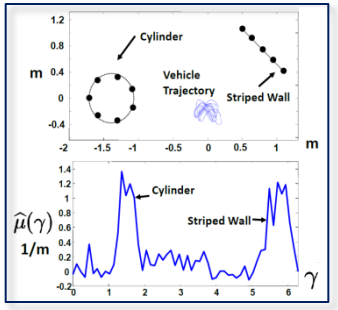
Propagation Phase Map

- **20 MHz miniature antenna enables phase coherent one-hop signaling through walls**
- UMich: Miniature antenna, propagation modeling, geolocation experiments (MAST CTA FY11-13)
- UCSB ICB / Iowa: Distributed array processing (MAST CTA FY13)
- ARL: Software defined radio @ 20 MHz, robotic control experiments (FY13)

Miniaturized HF for Communications & Geolocation



Long duration 3D mapping and navigation in GPS-denied relevant environments



Sensing and Perception for Processing Constrained Platforms

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Joint Experimental Testing Infrastructure – Building 507

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