Electrically Integrated Active Compliant Transmission (ACT) Actuation Technologies

The University of Michigan

Virginia Polytechnic Institute and State University

Pennsylvania State University

TACOM/ARDEC

Techno-Sciences, Inc.

Adaptive Materials, Inc.

DARPA Smart Structures Technology Interchange Meeting

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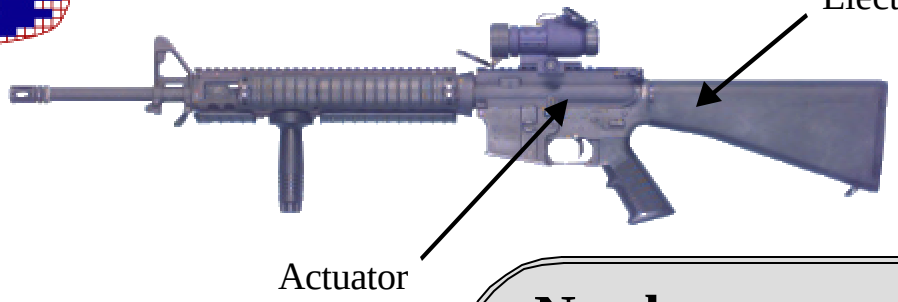
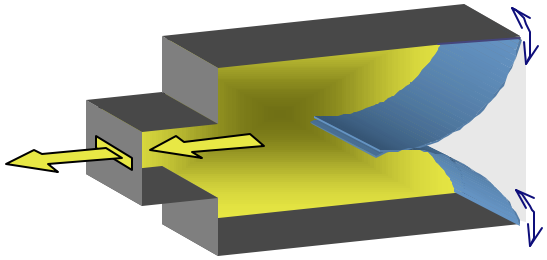
Baltimore, MD 21201

Motivation

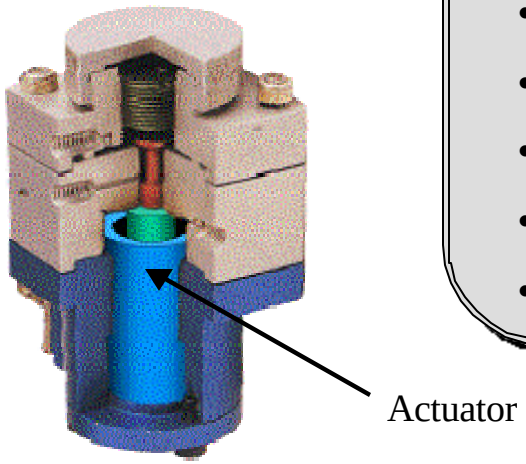




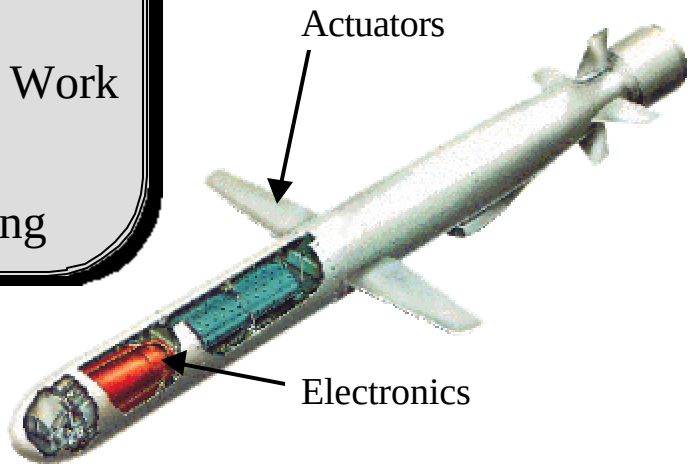
Synthetic Jet

Need

- Compact Size
- Large Stroke / High Force
- Fast Response
- Efficient
- High Power Density/ Specific Work
- High Reliability / Long Life
- Low Cost, Rapid Manufacturing



Fuel Injector



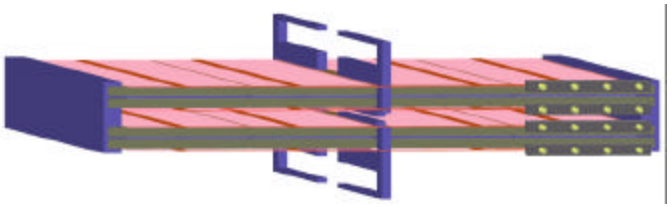
ACT

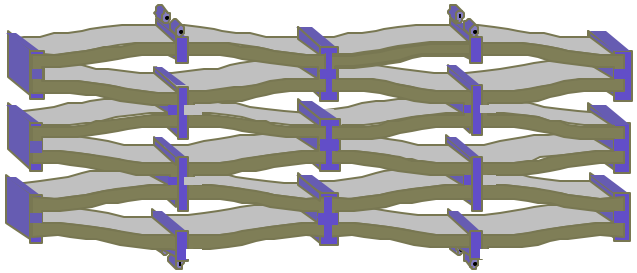
Project Goals

Goal: The synergistic development of *complete* piezoelectric actuation systems with integrated electronic drivers, material transduction, and novel internal compliant mechanical transmissions.

Objectives

- Compliant Internal Transmission with Integrated Electronics
  - compact size
  - large stroke, high force, fast response
  - efficient
  - high power density and high specific work
- Integrated predictive models and easy to use design tools
- Physical hybrid actuation demonstration
- Failure mode and life cycle data
- Low cost, rapid manufacturing
- Successful application demonstration





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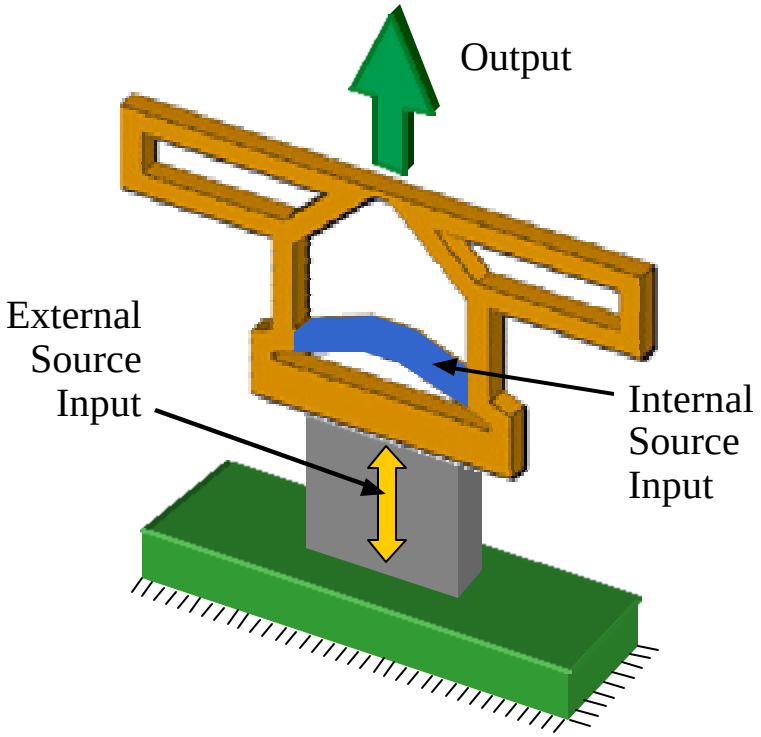
Active Compliant Transmission

Active Compliant Transmissions efficiently transform mechanical input from internal /external sources into mechanical output of a desired form (force,deflection, bandwidth, etc.)



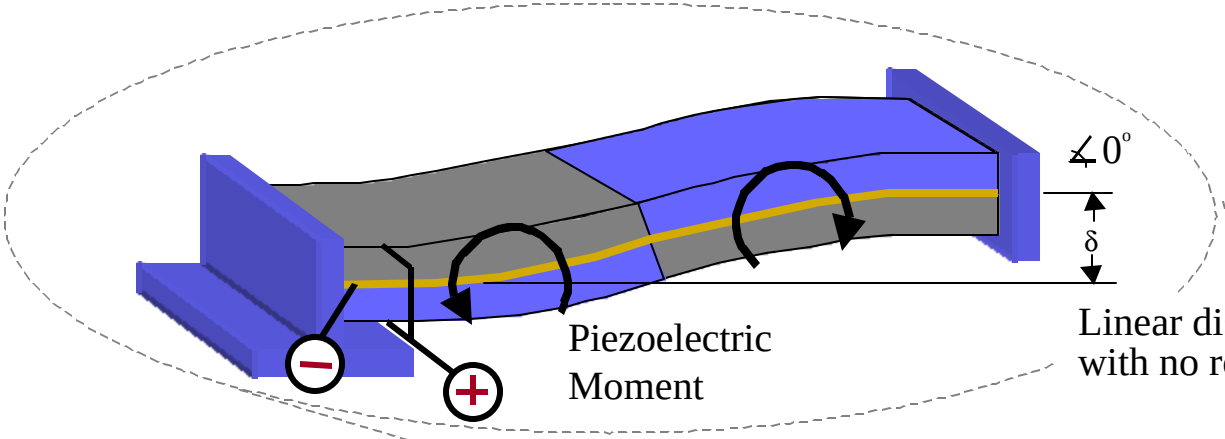
Unique because:

- Both external and embedded internal piezoelectric inputs
- Integrated electronics
- Load-bearing substrates with tailored stress regions according to material

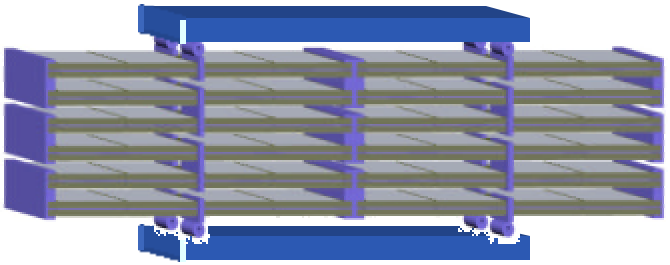
ACT

ACT Example

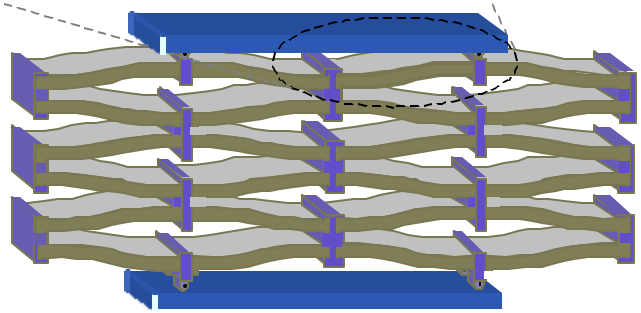
Basic Recurve Building Block Element



Unactivated Actuator



Activated Actuator



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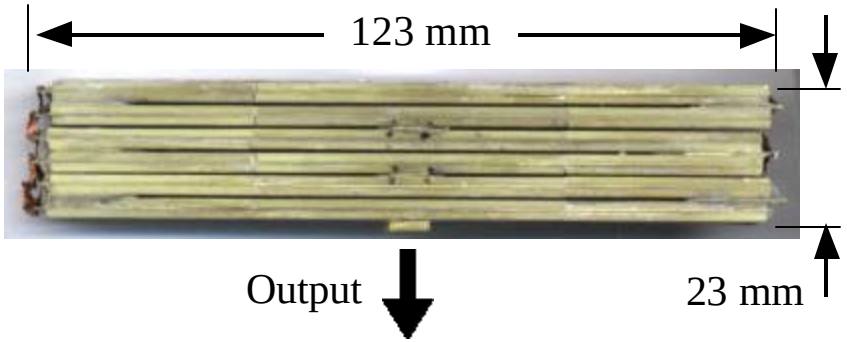
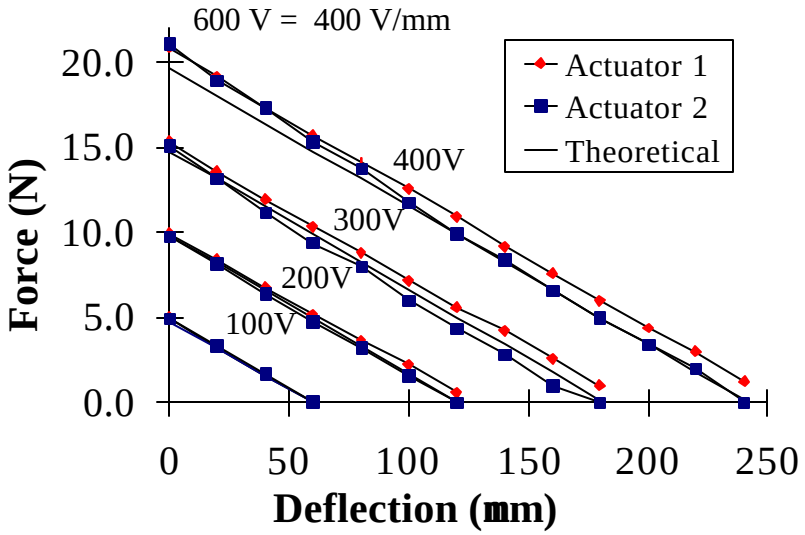
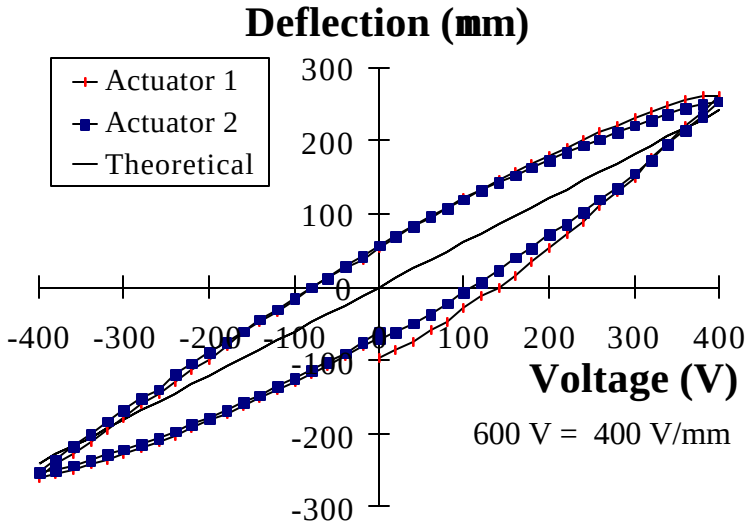
Recurve Experimental Performance

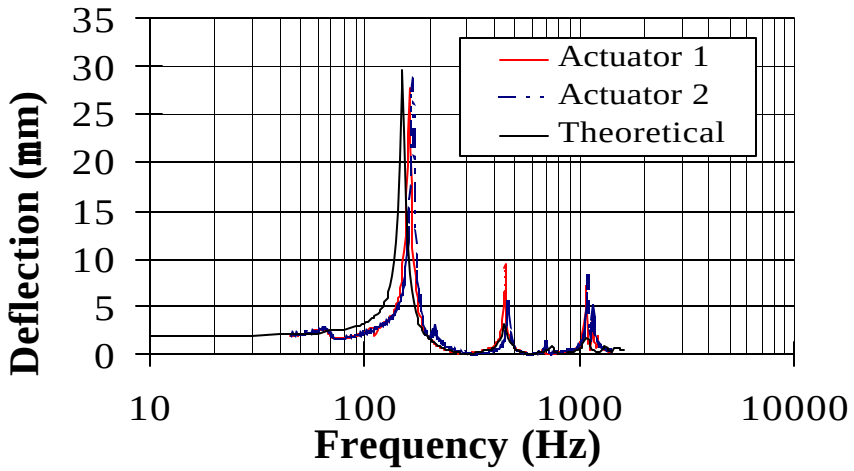
Actuator depth = 13 mm



PZT-5H / Brass Recurve Prototype







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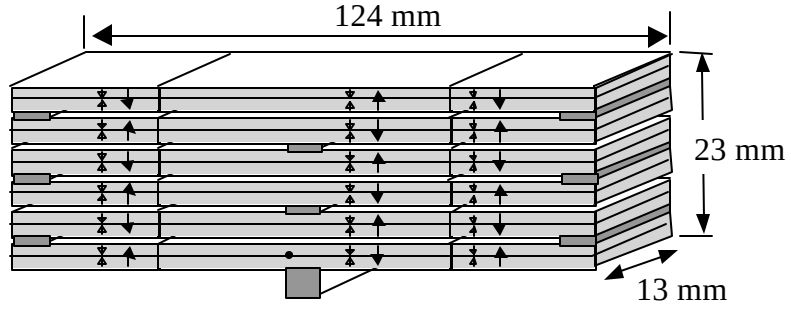
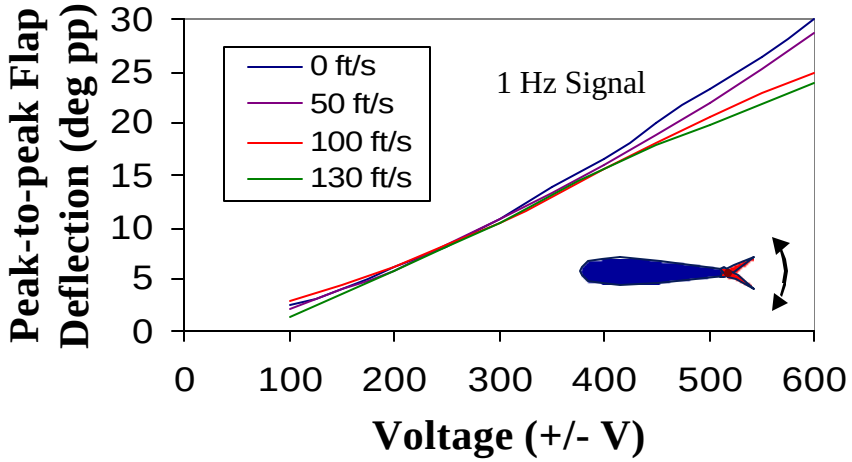
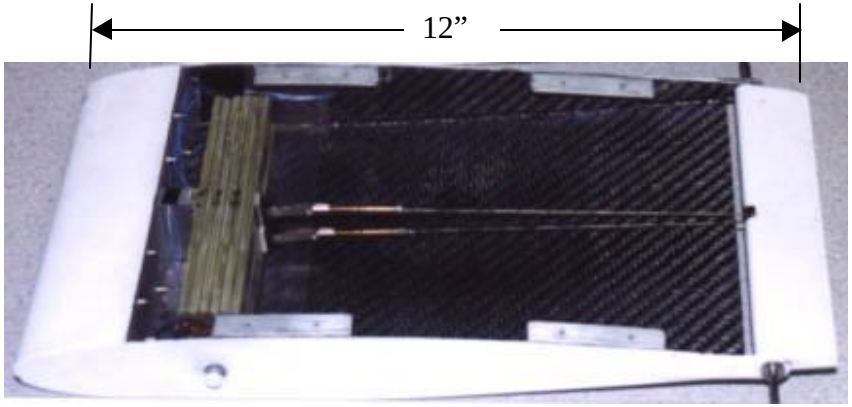
Recurve:
Wind Tunnel Flap Deflection Results

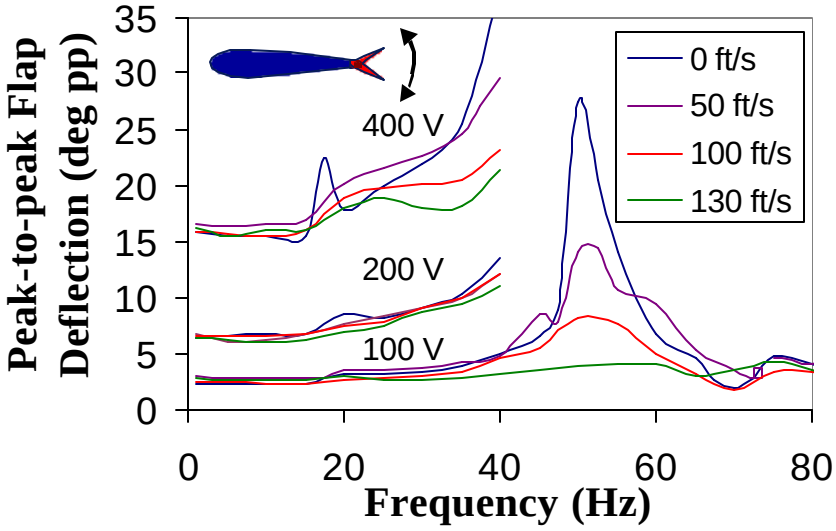


PZT-5H with brass substrate and spacer





NACA 0012 Rotor Blade Integrated with Recurve



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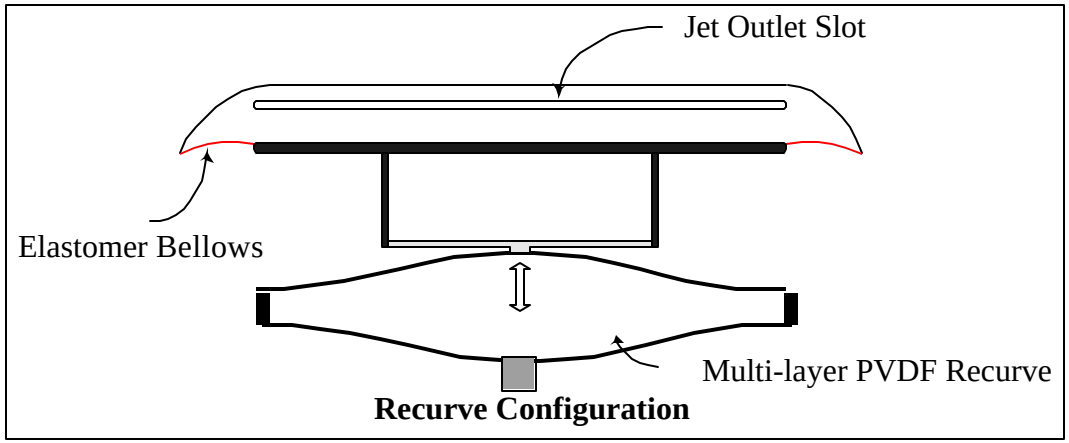
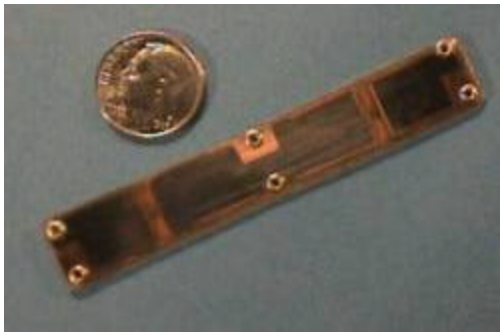
Low Frequency Synthetic Jet

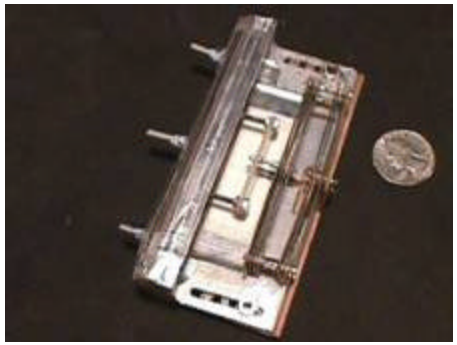
BAFCS SJ
V22 1/10 Scale Model Testing

- 0.8 mm Slot
- thin film PVDF 14 layer recurves
- > 20 m/s at 110 Hz
- Requirement 0.8 Newton & 2.5 mm

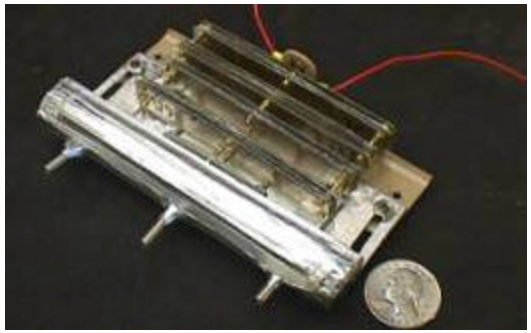




PVDF recurve element



Single Cell Recurves



Two Cell Recurves

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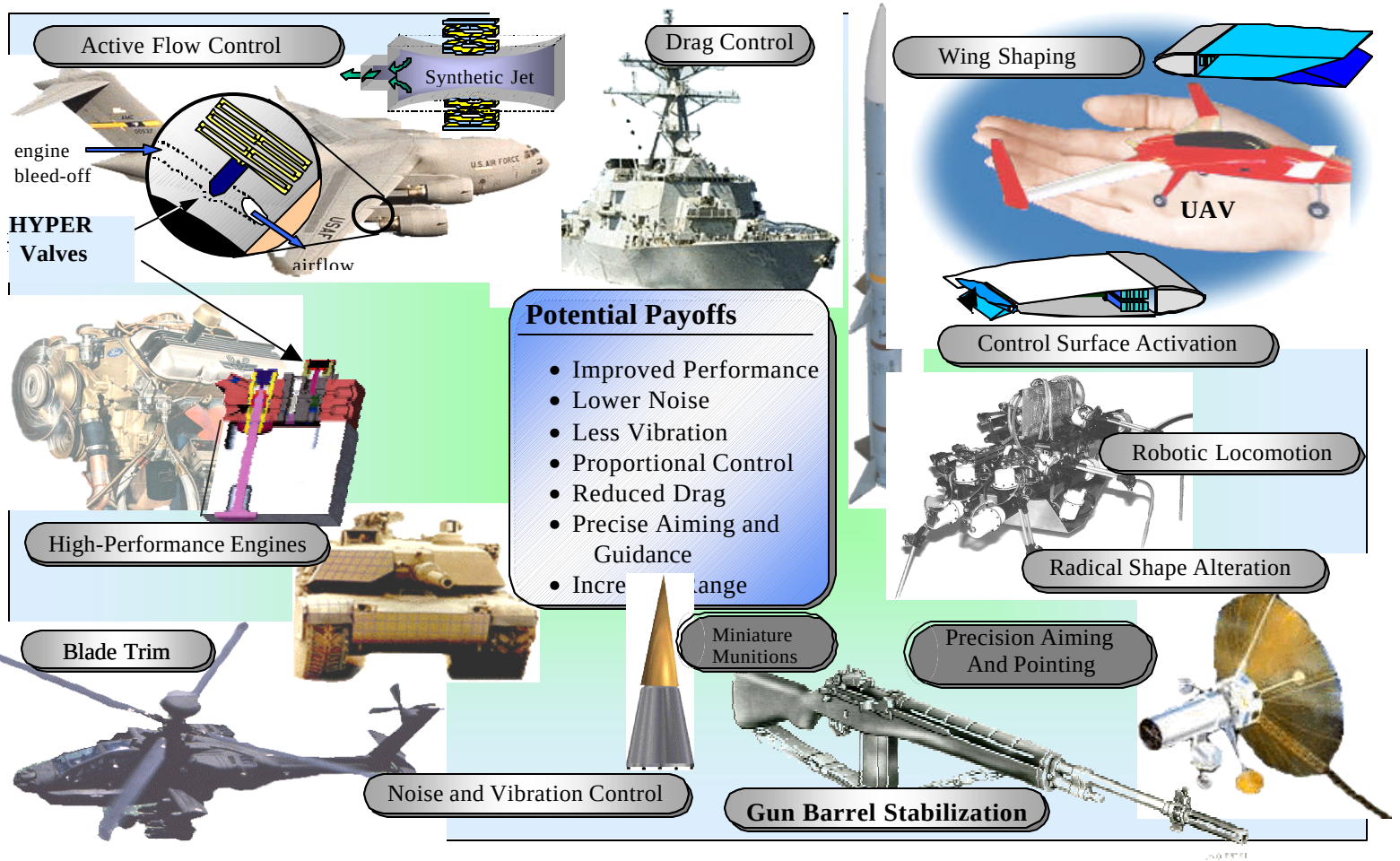
Potential Military Applications



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INertially STAbilized Rifle (INSTAR)

Marksmanship fundamentals require extensive and periodic training to master and degrade drastically under combat stress.

Reduction in Fine motor Skills due to: Accelerated Heart Rate, Fatigue, Stress, and Environmental Conditions

Maintaining desired aim point vs. natural aim point

Improper Breathing

Recoil avoidance/Anticipation

Improper Trigger Squeeze

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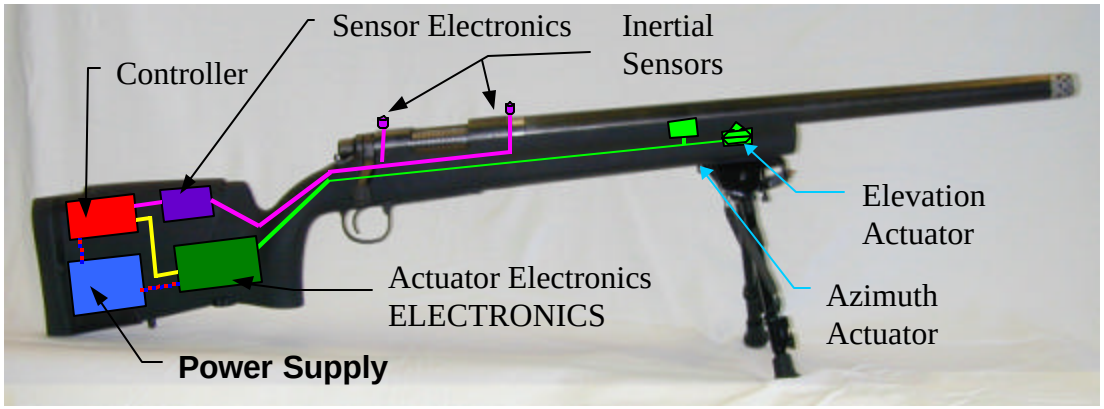
INSTAR Demonstration

Goal: Eliminates aiming error sources by stabilizing barrel assembly (2 DOF), effectively compensating for small user induced disturbances.

Potential Payoffs:

- Improved Soldier Survivability
- Increased lethality and "stowed" kills
- Reduced ammunition requirements/cost/logistics burden
- Faster training cycles



Customers:

- Material Developers – Joint Service Small Arms Program, PM Small Arms
- Requirement Developers – Infantry School, USMC Special Operations, Rangers

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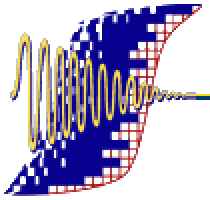
Team Members and Primary Contributions



CORE TEAM

Diann Brei, Principal Investigator
UM - Mechanical Engineering
Project Administrator, Design Tools, Actuation System Architecture Design, Integrated Modeling, Actuator Testing/Qualification

Mary Frecker
Penn State - Mechanical Engineering
Compliant Transmission Optimization and Design Tools

Doug Lindner
Virginia Tech
Electronics. Design, Fabrication, and Testing

John Halloran
UM - Materials Science
Material Study, Reliability Study, Material Testing and Characterization

Aaron Crumm
Manufacturing
Design for Manufacturability, Manufacturing Process Development, Actuator Prototype Fabrication, Cost Analysis, Transition to Commercial Market

ELECTRICALLY INTEGRATED COMPLIANT TRANSMISSION ACTUATION TECHNOLOGY

DEMONSTRATION PLATFORMS

INSTAR

Chris LaVigna
TSI
- Gun Design
- Control Design
- Open and Closed Loop Demonstration
- Transition to Commercial Markets

Mike Mattice and Robert Testa
TACOM/ARDEC
- Gun Specification
- Firing Demonstration
- Transition to Military
- Gun Platforms

POTENTIAL

Synthetic Jets
- Boeing

Precise Munitions
- TACOM/ARDEC

HYPER Valves
- Saturn
- Eaton
- ARC-Tacom/ARDEC

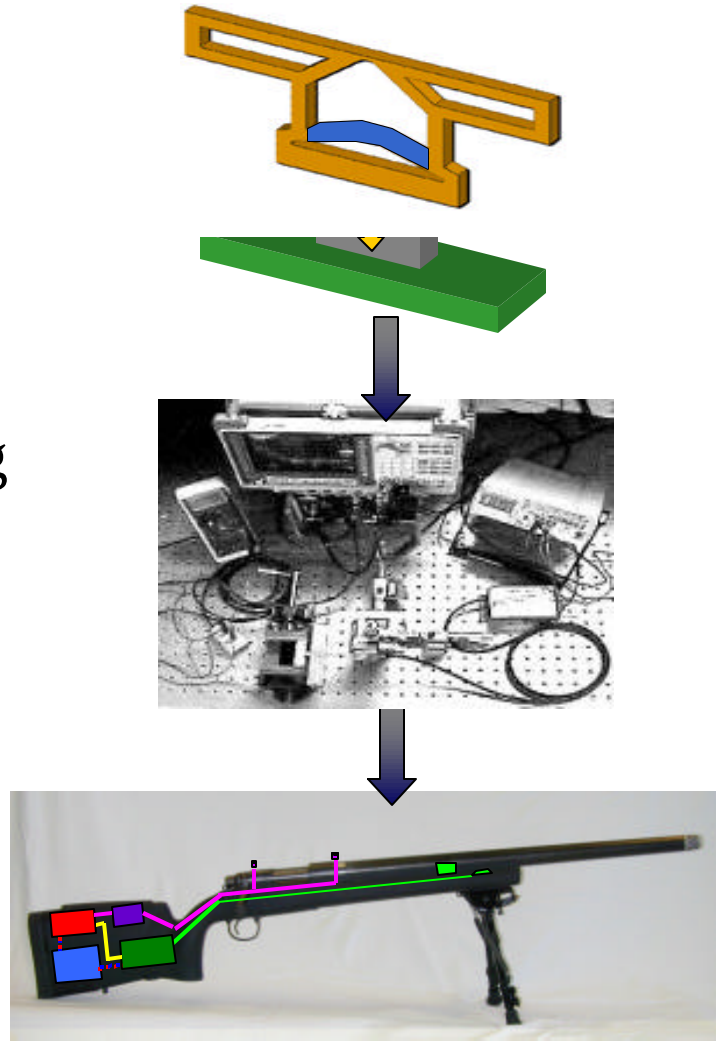
MULTIPURPOSE MARKETS

- MILITARY
- INDUSTRIAL
- COMMERCIAL
- SPORTS
- LAW ENFORCEMENT

ACT

Approach

- Active Compliant Transmission Optimization
- Integrated Electronic Drivers
- Integrated Actuation System Modeling
- Actuator Manufacturing
- Actuator Performance Validation
- Reliability Study
- Transition to Military/Commercial Platforms



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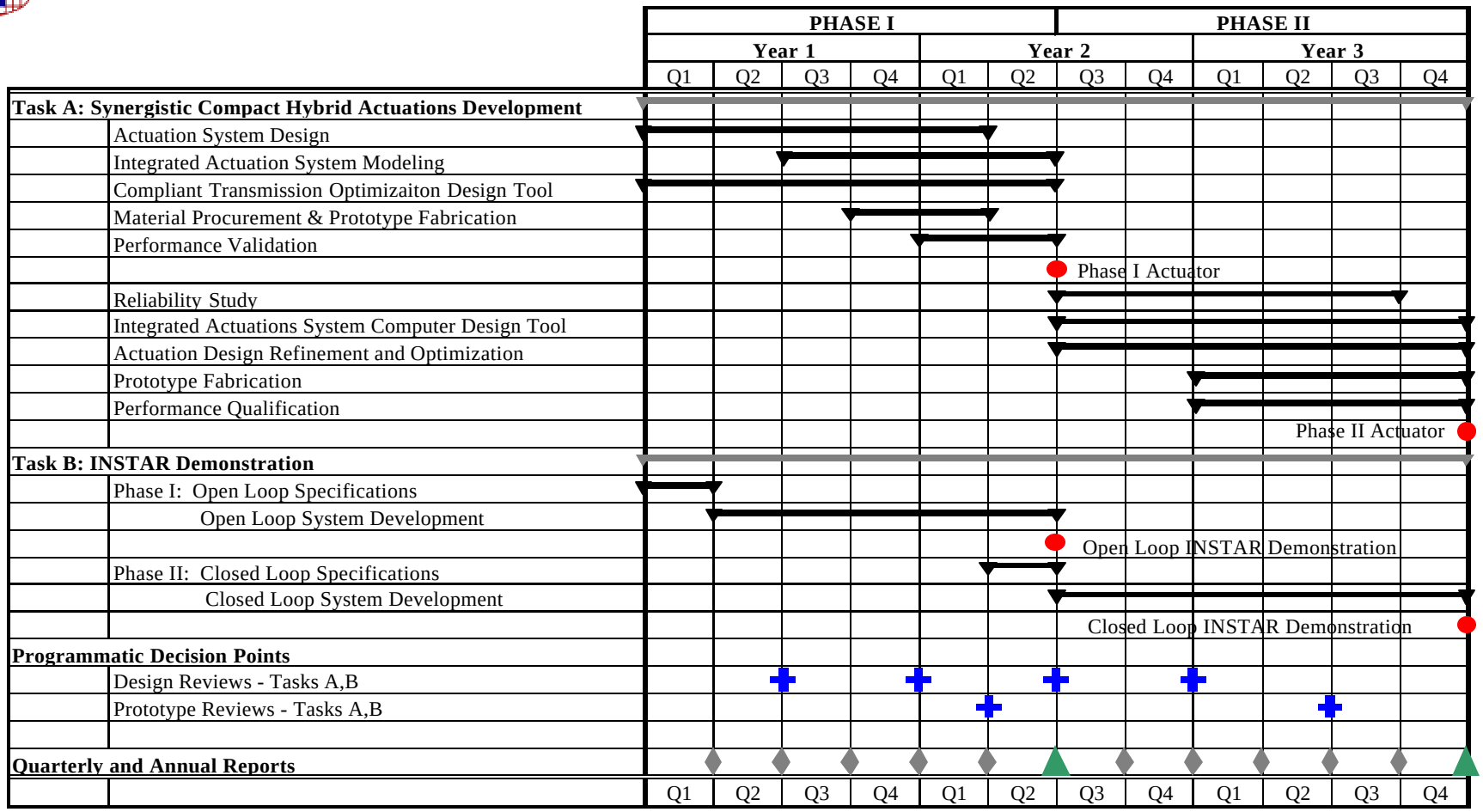
Implementation Schedule



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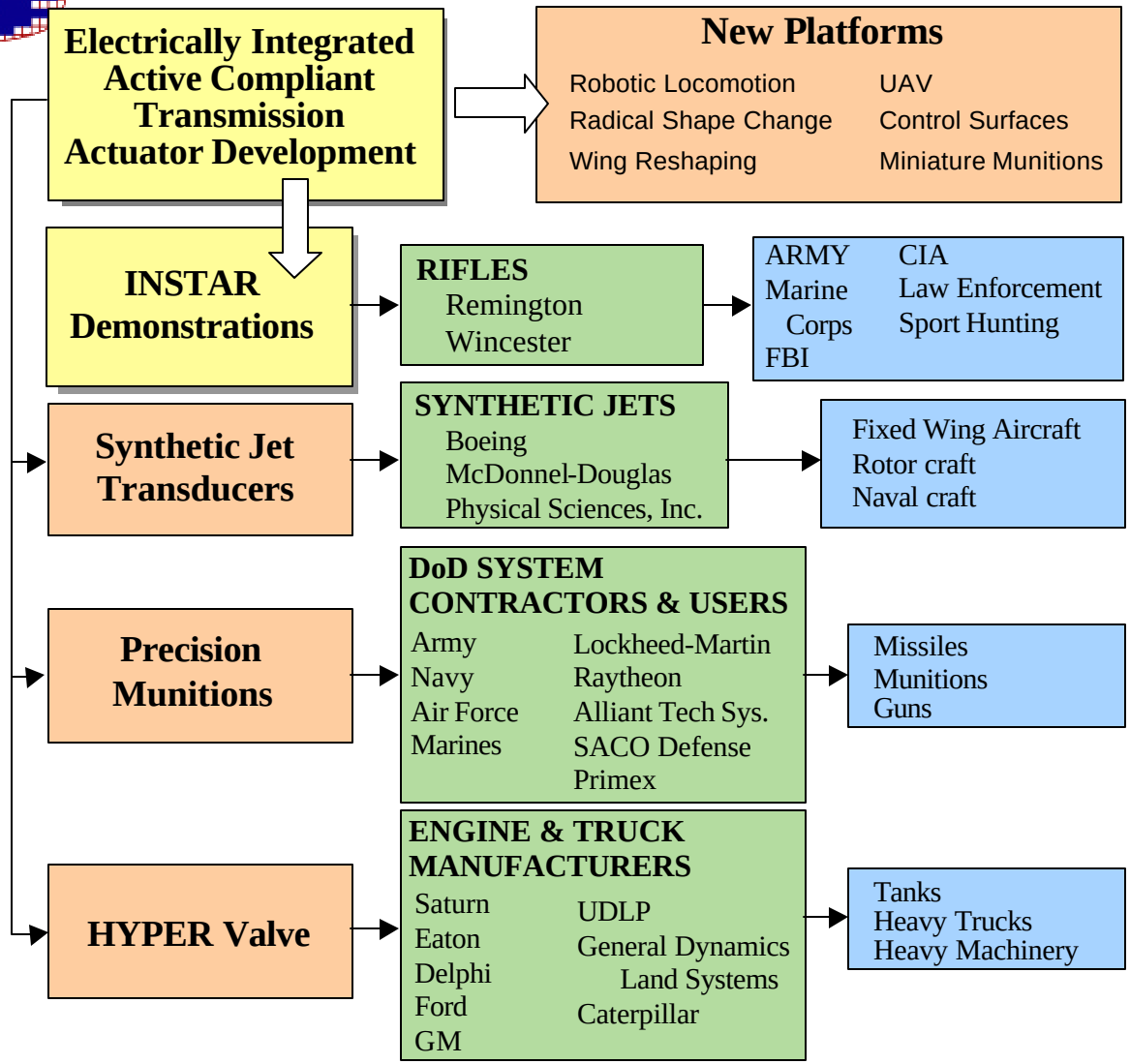
Transition Plan



- **Establish Customer Advisory Board**
  - **Industrial**
  - **Military**
  - **Law Enforcement**
- **End of Phase I and Phase II Demonstration to Customer Advisory Board**
- **Ongoing Demonstrations to Potential Customers**

ACT