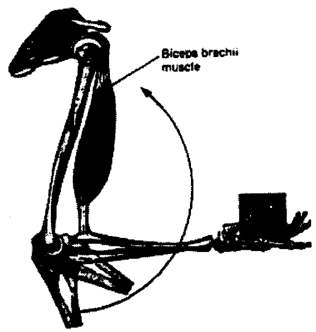
LOW MASS MUSCLE ACTUATORS (LoMMAs)



Telerobotic Task Sponsored by NASA HQ, Code S

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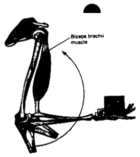
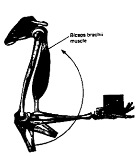
OUTLINE

- Background and Motivation
- FY'97 Level 1 Milestones and Deliverables
- Two baseline actuation materials
  - Ion-Exchange Membrane-Platinum Composites (IEMP)
  - Longitudinal Electrostatic Actuators (LEAs)
- Application of IEMP
  - Gripper
  - Surface Wiper
- Application of LEAs
  - Lifter of a miniature robotic arm
- Comb-Electrode Tailored-Field EAP
- Future Plans
- Publications and New Technology Reports
- LoMMAs Team Members



BACKGROUND AND MOTIVATION

- NASA is using actuation devices for many space applications.
- There is an increasing need for miniature, low mass, low power consuming, inexpensive actuators.
- Existing transducing actuators such as piezoceramics are inducing limited displacement levels.
- Electroactive polymers (EAP) ability to induce large displacements offer an enabling technology for unique mechanisms.
- EAP are activated by an electrical field and they can be used to emulate biological muscles.



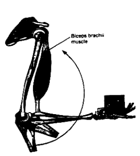
COMPARISON BETWEEN EAP AND WIDELY USED TRANSDUCING ACTUATORS

Property	EAP	EAC (Piezoceramics)	SMA
Actuation displacement	>10%	0.1 - 0.3 %	<8% short fatigue life
Force (MPa)	0.1 - 3	30-40	about 700
Reaction speed	μsec to sec	μsec to sec	sec to min
Density	1- 2.5 g/cc	6-8 g/cc	5 - 6 g/cc
Drive voltage	4 - 7 V	50 - 800 V	NA
Power consumption	m-watts	watts	watts
Fracture toughness	resilient, elastic	fragile	elastic

FY’97 LEVEL 1 OBJECTIVES

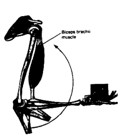
Develop:

- EAP actuated components of 2 degree-of-freedom miniature robotic arm.
- EAP bending muscle with 15% enhanced force actuation capability over the FY'96 result.



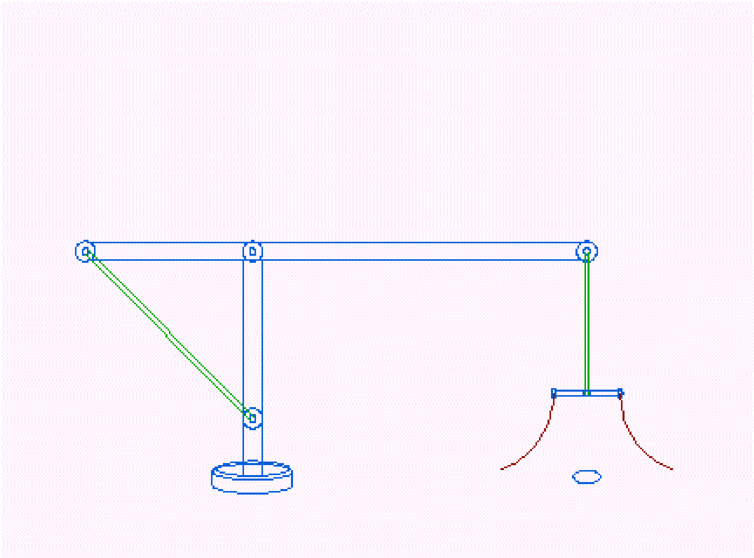
DELIVERABLES

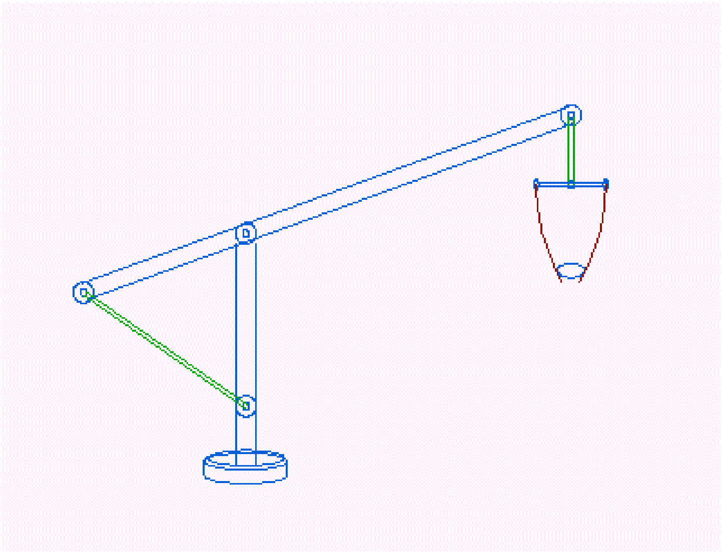
- Developed thick ionomer muscle actuators with more than 20% force delivering capability.
- Developed 4-finger grippers which can lift and hold a rock weighing 10.3 g.
- Demonstrated the applicability of ionomer muscle actuators as a surface wiper removing dust from a glass plate.
- Developed a longitudinal electrostatic actuator with more than 12% displacement. A scrolled EAP rope lifted more than 10 g.
- Demonstrated actuation components for a 2 DoF miniature robotic arm.



ELECTROACTIVES POLYMERS (EAP)

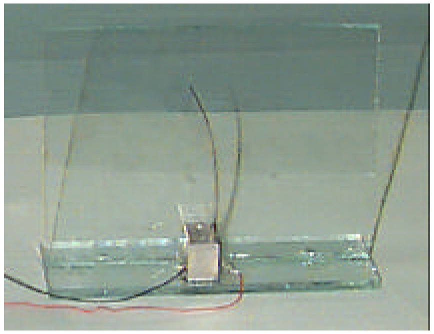
POTENTIAL APPLICATION - SAMPLE HANDLING AND MANIPULATION



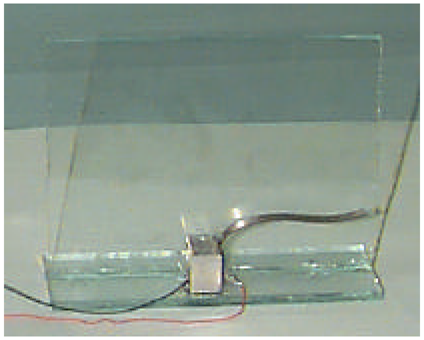


BENDING EAP ACTUAOR

Reference



Activated

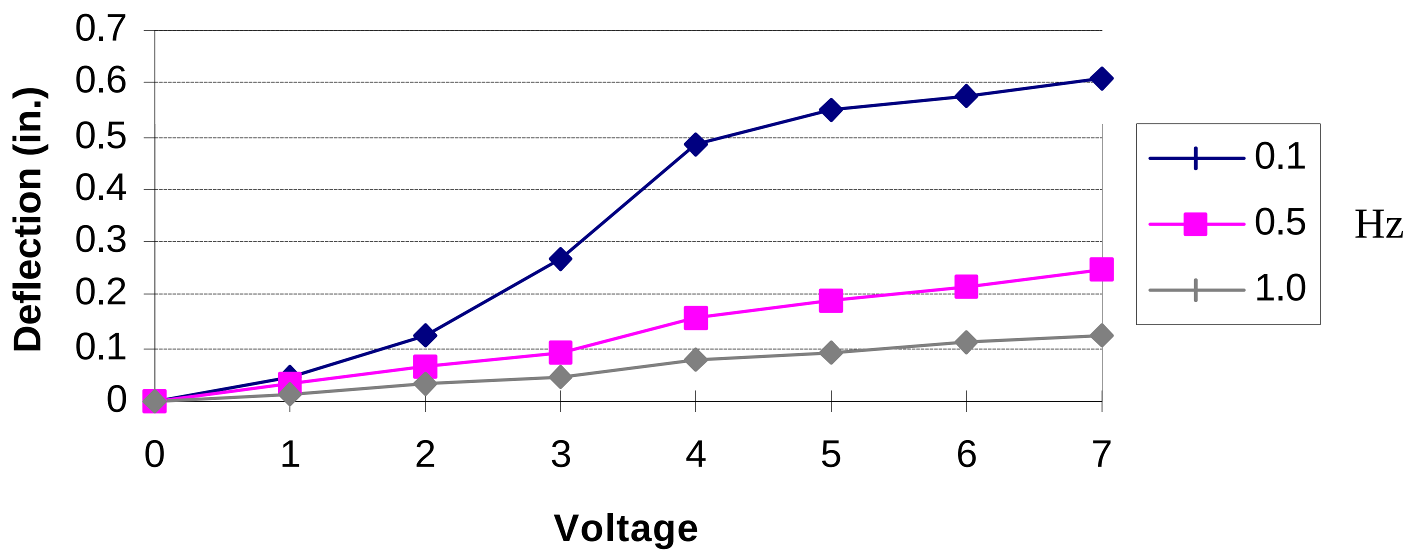


Three critical factors affecting the operation of IEMP muscle's:

- Presence of moisture in the film
- Presence of conductive ionic species in the membrane
- Penetration of platinum (or alternative noble metal) particles into the membrane

BENDING EAP ACTUATOR

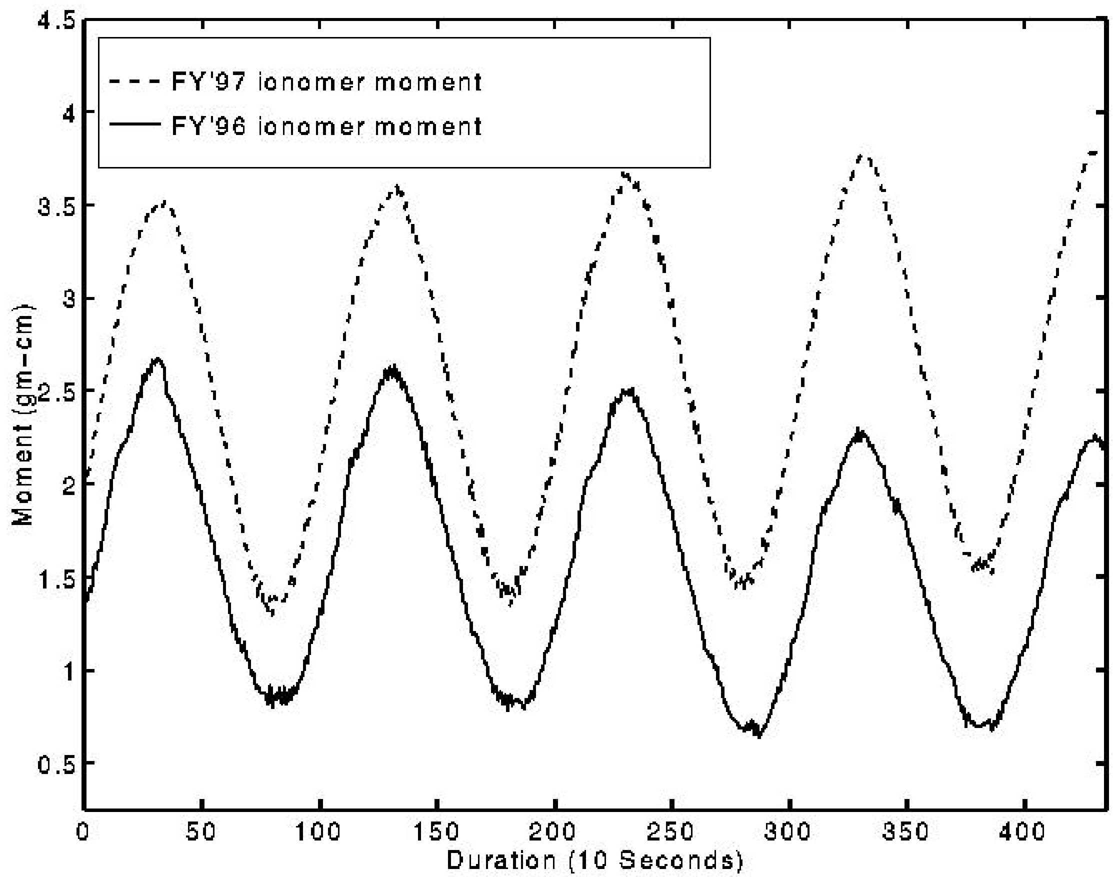
DISPLACEMENT RESPONSE

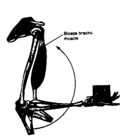


- The deflection of the bending actuator (1x.25x.02-inch IEMP composite film processed with NaOH) as a function of the applied voltage and frequency (Hz).

BENDING EAP ACTUATOR

FORCE DELIVERING RESPONSE

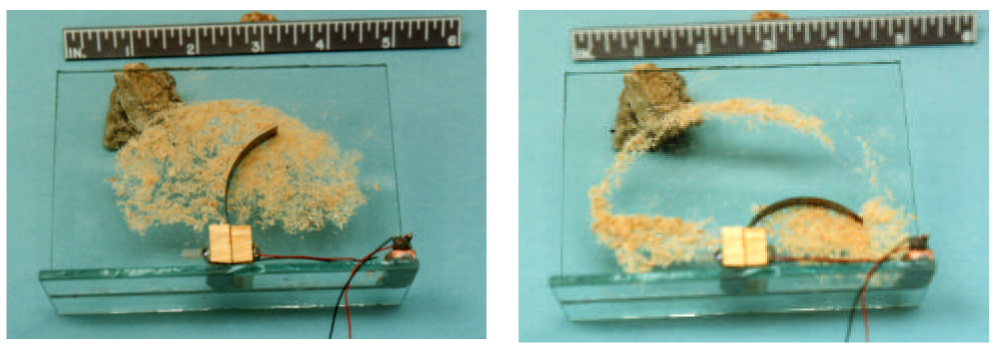




APPLICATIONS OF BENDING EAP ACTUATOR

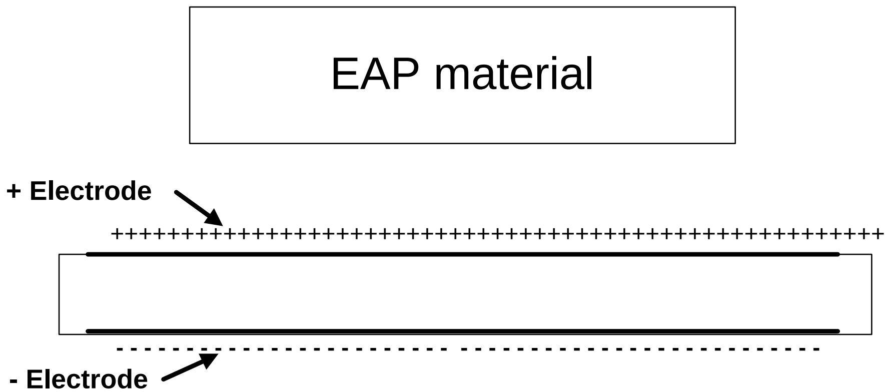
Gripper

Wiper



LONGITUDINAL EAP ACTUATOR

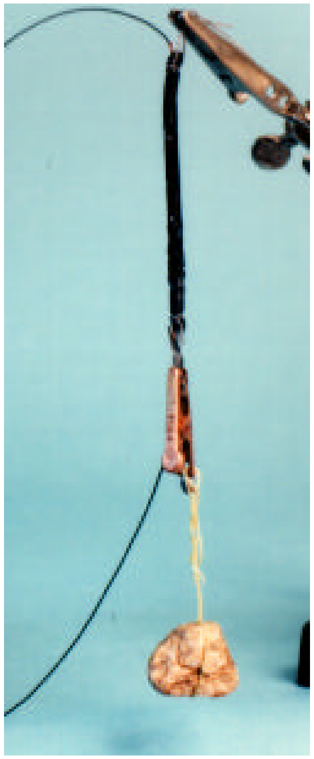
Under electro-activation, an EAP film with electrodes on both surfaces expands laterally.

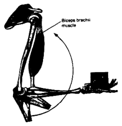


EAP film subjected to 25 V/:m induced over12% extension

ELECTROSATICALLY ACTIVATED ROPE
USING SCROLLED EAP FILMS

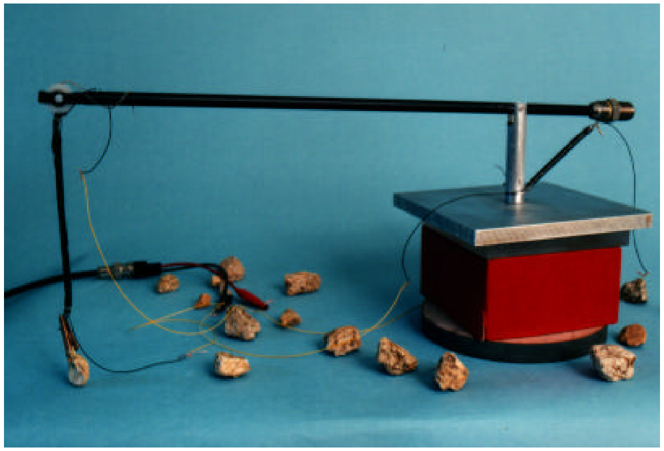
Rolling electroded EAP films to a scrolled rope allows to form an easy to use actuator. The shown rope actuator is lifting about 10-g rock.

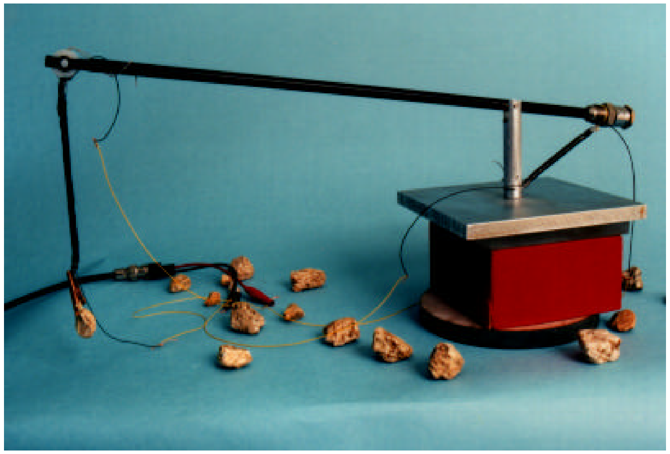




APPLICATIONS OF THE LONGITUDINAL EAP ACTUATOR

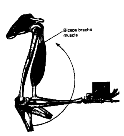
Lifter





FUTURE PLANS

- Modeling ion-exchange membrane platinum composite bending ionomer Q2 FY98
- Investigate cryovac performance of the linear and bending EAPs Q3 FY98
- Demonstrate controlled dust removing surface wiper driven by bending ionomers Q4 FY98
- Demonstrate muscle action in a robotic operation & controlled actuation Q4 FY98
- Servo-control and miniature EAP drive electronics Q3 FY99
- Low temperature operational EAP muscle Q4 FY99
- Demonstrate multi-DoF dexterous robotic arm Q2 FY00
- Integrate EAP-driven dexterous multi-DoF arm into a sample manipulation testbed Q4 FY00



PUBLICATIONS AND NEW TECHNOLOGY REPORTS

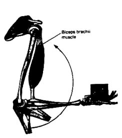
New Technology Report

- Y. Bar-Cohen, B. Joffe, J. Simpson and T. Xue, “Electroactive Muscle Actuators (EMA),” New Technology Report, Item No. 9649, Docket 20017, August 22, 1996. Provisional Patent disclosure (Authorized September 10, 1997). Modified on Sept. 15, 1997.
- Y. Bar-Cohen, T. Xue, M. Shahinpoor and S.-S. Lih., "Electroactive Polymer Gripping End-Effector," New Technology Report, Item No. 9741, Docket 20103, July 15, 1997. U.S. Provisional Patent CIT 2665 (Submitted on July 25, 1997 under reference 06618/185001)
- Y. Bar-Cohen, T. Xue and M. Shahinpoor, "Surface Wiper Actuated by Electroactive Polymers (SWEP)," Submitted as a New Technology Report, August 14, 1997.

Publications

- Y. Bar-Cohen, T. Xue, B. Joffe, S.-S. Lih, P. Willis, J. Simpson, J. Smith, M. Shahinpoor, and P. Willis, “Electroactive Polymers (EAP) Low Mass Muscle Actuators,” Proceedings of SPIE, Vol. SPIE 3041, Smart Structures And Materials Symposium, Enabling Technologies: Smart Structures and Integrated Systems, ISBN 0-8194-2454-4, SPIE, Bellingham, WA (June 1997).

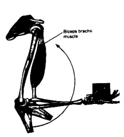
- Y. Bar-Cohen, T. Xue, M. Shahinpoor, J. Simpson, and J. Smith, "Flexible, Low-mass Robotic Arm Actuated by Electroactive Polymers and Operated Equivalently to Human Arm and Hand", Proceedings of the Robotics 98: The 3rd Conference and Exposition/Demonstration on Robotics for Challenging Environments Sponsored by American Society of Civil Engineers, Albuquerque, New Mexico, April 26-30, 1998 (to be published).



PUBLICATIONS AND NEW TECHNOLOGY REPORTS (Cont.)

<u>Presentations</u>

- Y. Bar-Cohen, "Application of Space Technology to NDE at JPL," ASNT Local Section, Downey, CA, October 8, 1996.
- Y. Bar-Cohen, T. Xue, B. Joffe, S.-S. Lih, P. Willis, J. Simpson, J. Smith, M. Shahinpoor, and P. Willis, "Electroactive Polymers (EAP) Low Mass Muscle Actuators," SPIE International Conference on: Smart Structures and Materials Symposium, Enabling Technologies: Smart Structures and Integrated Systems, San Diego, CA, 3-6 March 1997.
- Y. Bar-Cohen, "NDE and Telerobotics at the Jet Propulsion Laboratory (JPL)", Technical Seminar, The University of Texas at El Paso (UTEP), April 29, 1997.



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