



Damage Characterization using Nanocomposite Sensors and Tomography

UNIVERSITY OF CALIFORNIA – SAN DIEGO

Han-Joo Lee and Ken Loh*

*Professor and Vice Chair
Department of Structural Engineering
Materials Science & Engineering Program

2019 IEEE International Conference on Wireless for Space and Extreme Environments

Ottawa, Canada
October 16, 2019



Civil



Geotechnical



Automotive

Structure?

Materials + Geometry + Function

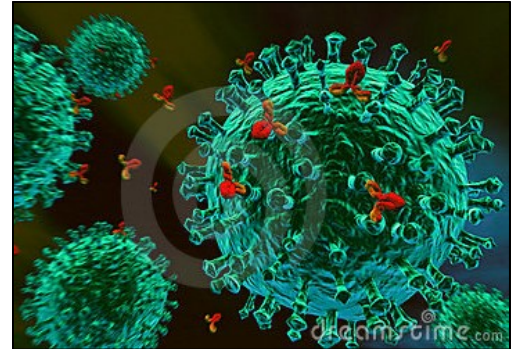
Aerospace



Marine



Biological



Damage and Degradation



Environment



Repeated loading



Impulse-type events



Natural disasters



Extreme events



Manmade



To safeguard and advance the capabilities of our structural and human assets by designing stimuli-responsive materials coupled with novel excitation, interrogation, and analytical methods

Enhancing Warfighter Performance

- Soft robotics
- *Active skins*

Asset Sustainment

- *Sensing skins and meshes* for distributed sensing
- Nondestructive damage imaging

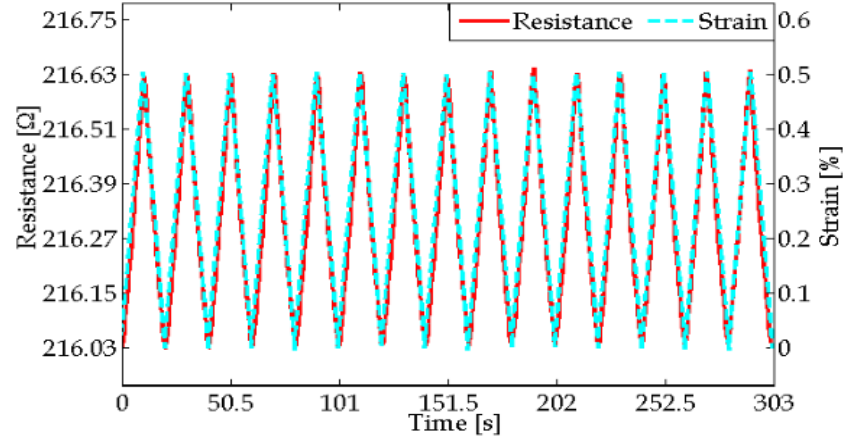
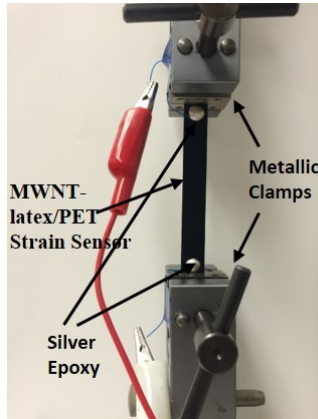
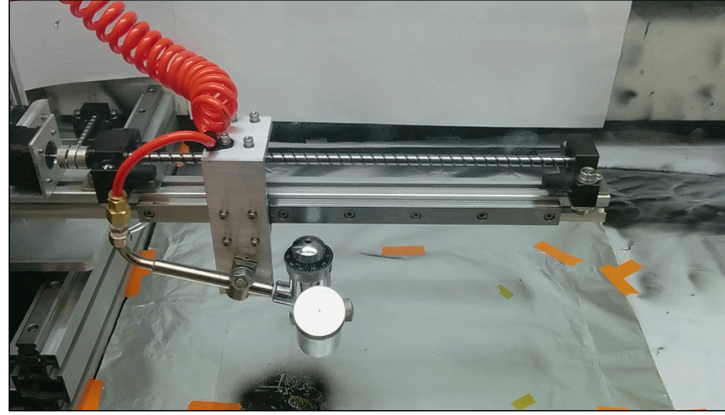
Warfighter Protection

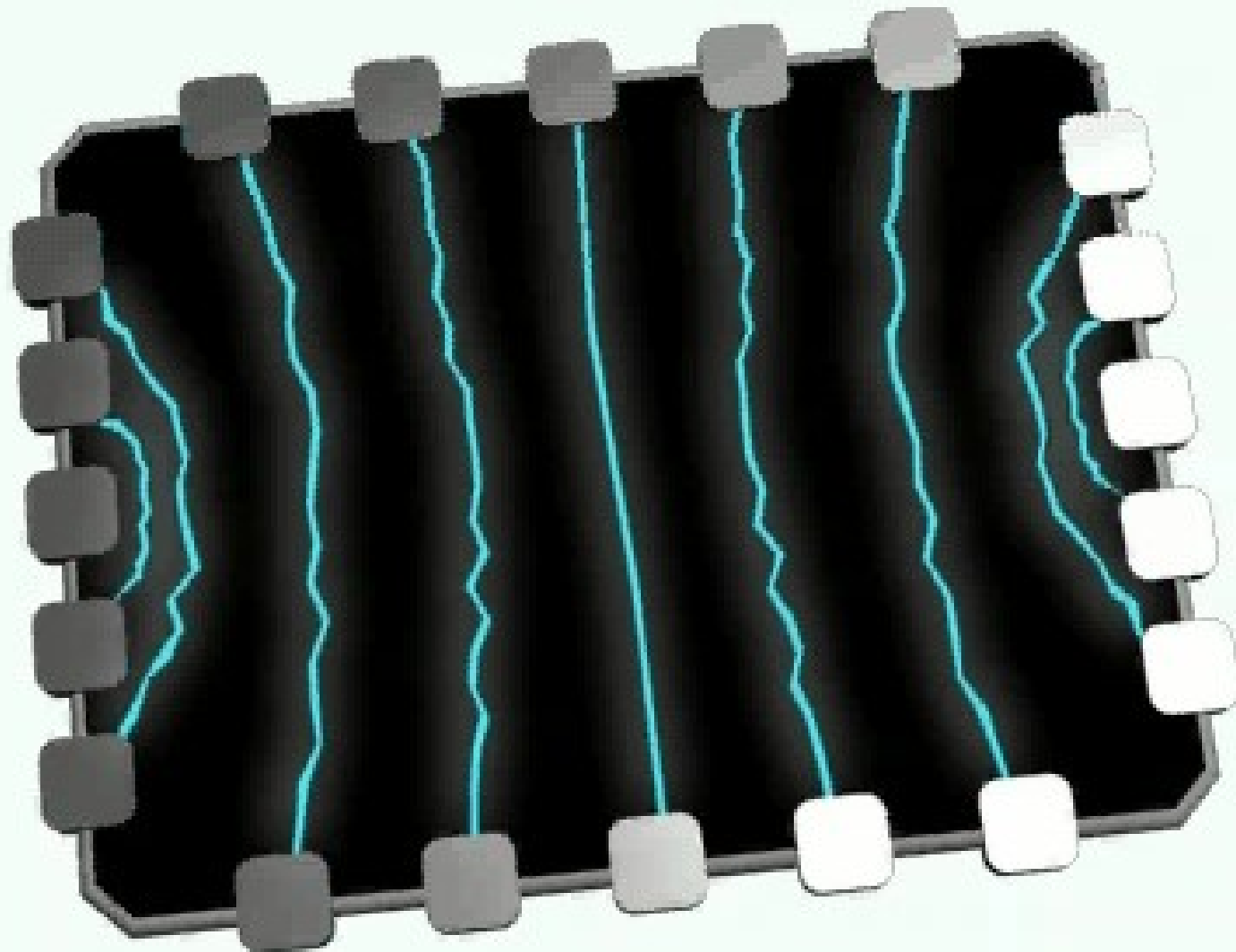
- Wearable fabric-/tattoo-like sensors
- Field-deployable medical imaging
- Smart and flexible armor



1. Asset Sustainment

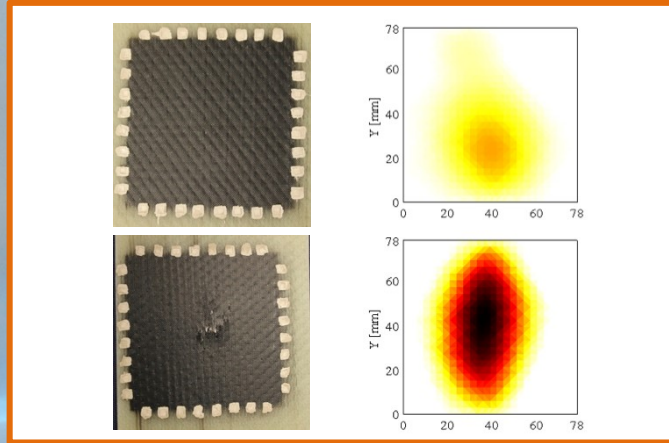
STRAIN SENSING RESPONSE



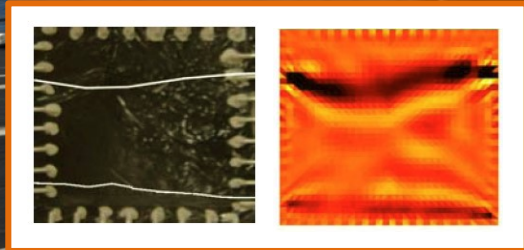


Sensing Skins

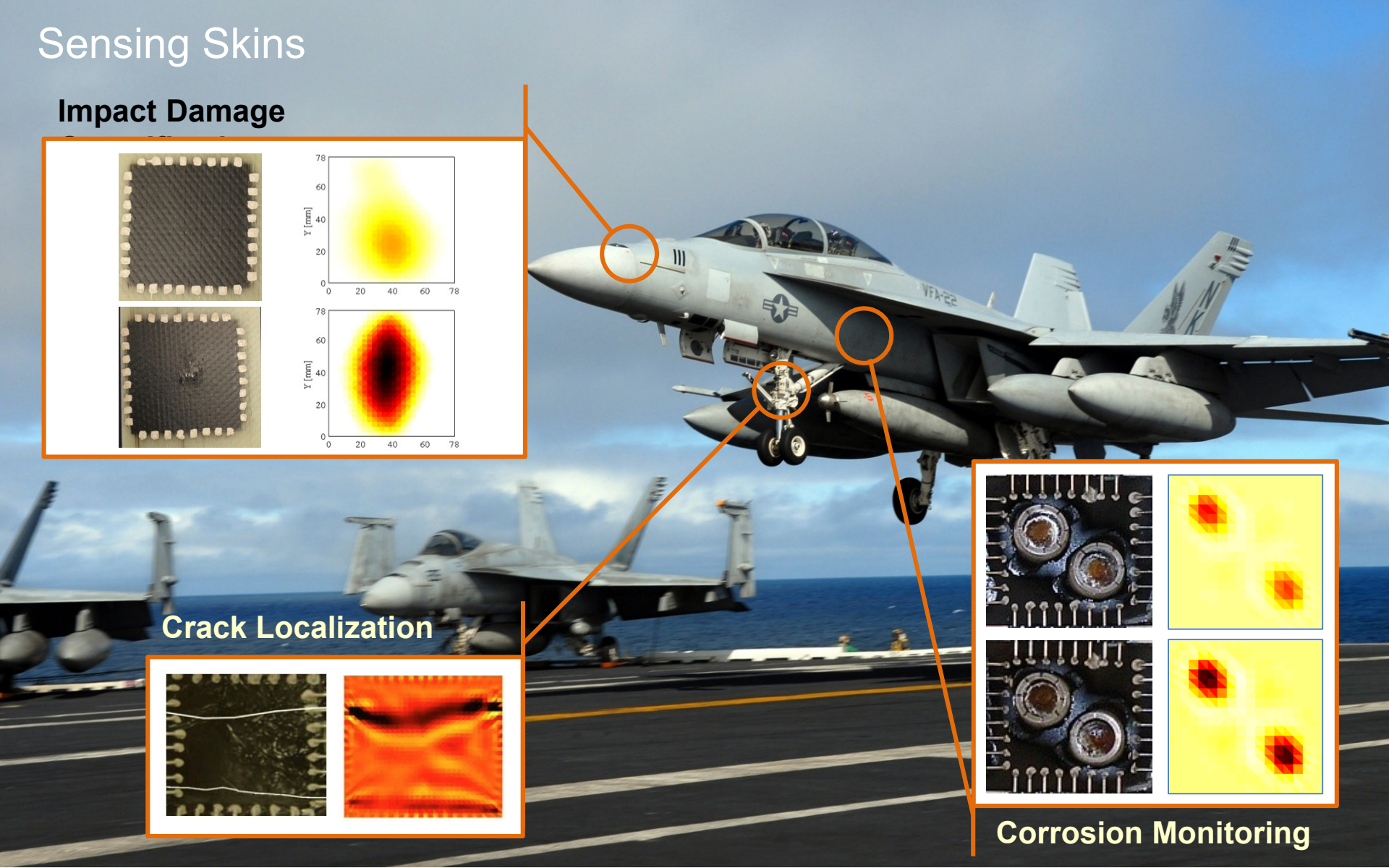
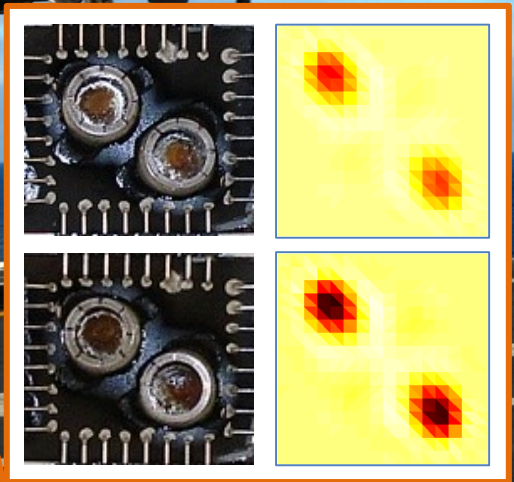
Impact Damage

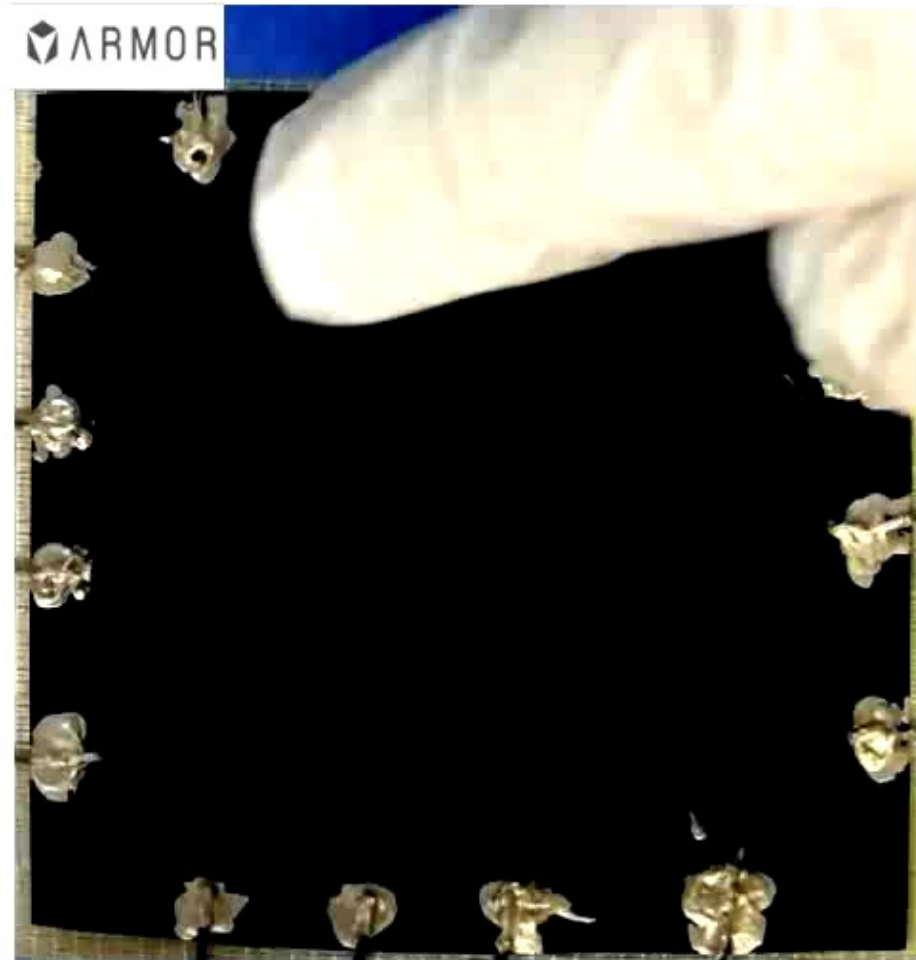


Crack Localization

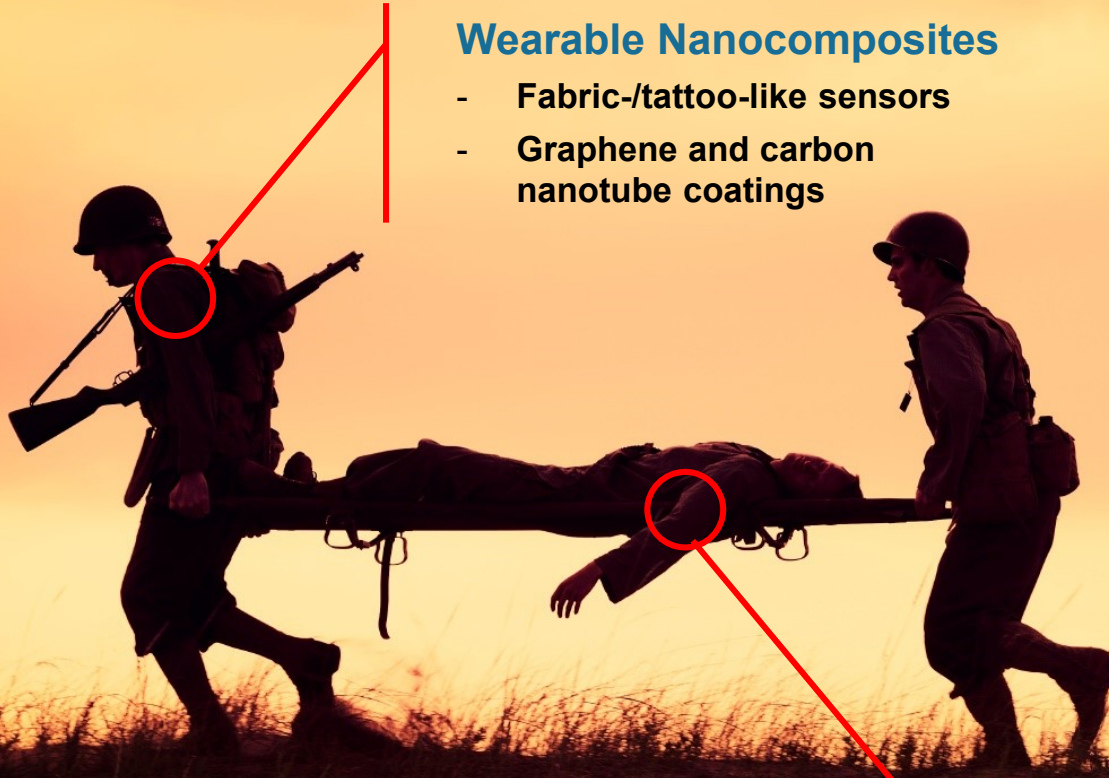


Corrosion Monitoring





2. Warfighter and Asset Protection



Wearable Nanocomposites

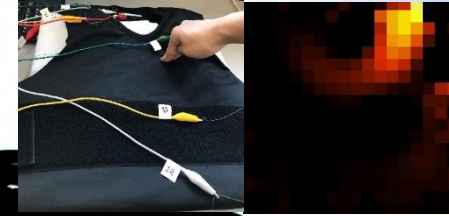
- Fabric-/tattoo-like sensors
- Graphene and carbon nanotube coatings

Deployable Medical Imaging

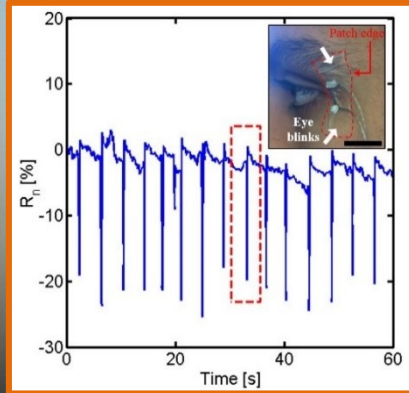
- Electrical capacitance tomography (ECT)

Wearable Sensors

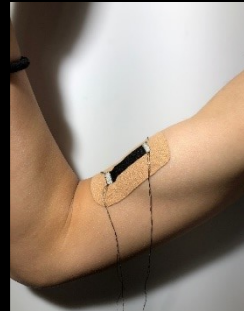
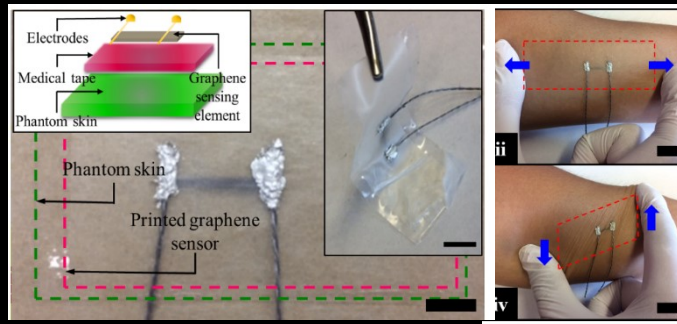
Smart Armor



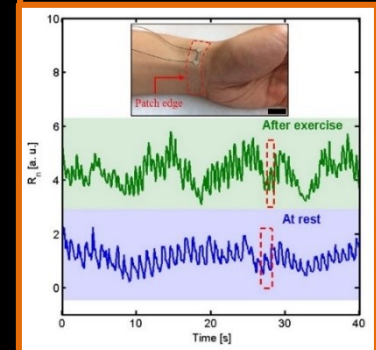
Eye Blinking



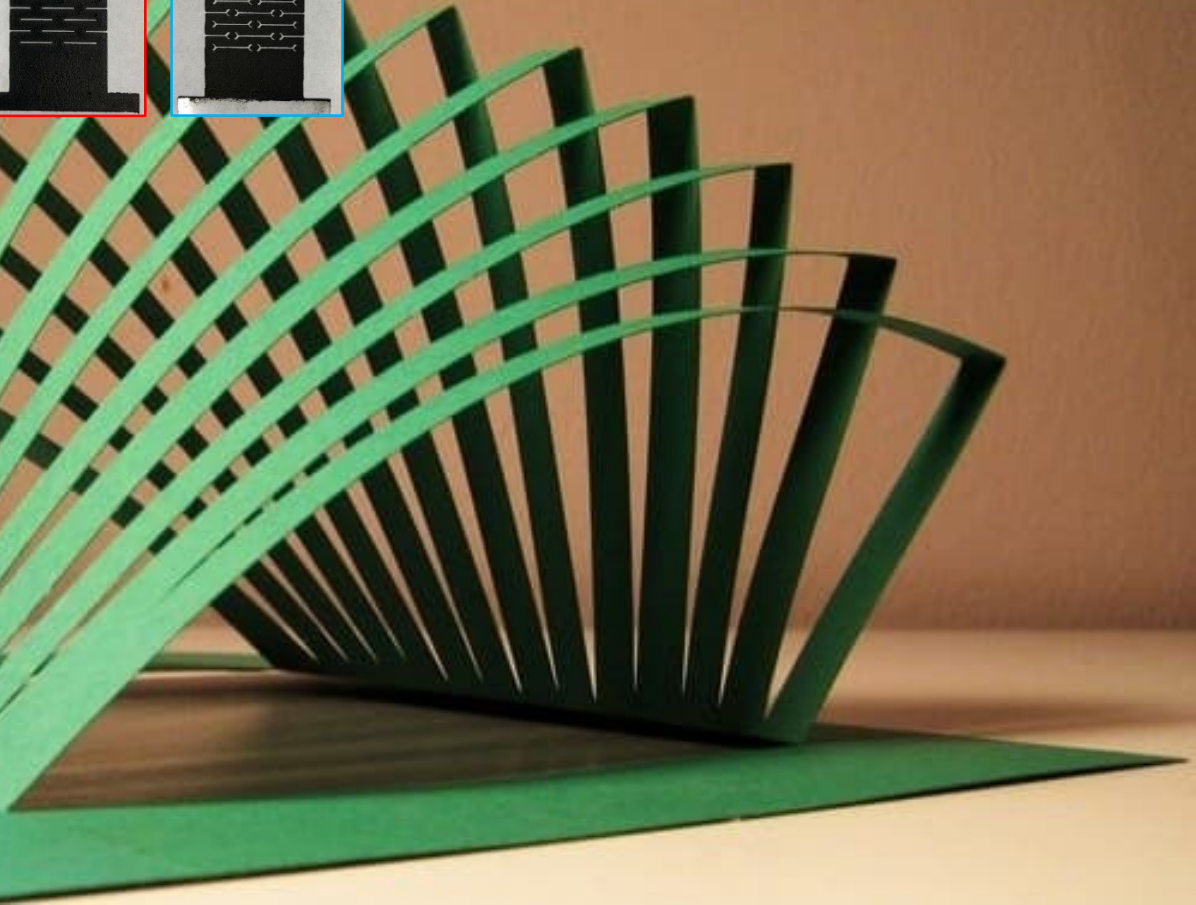
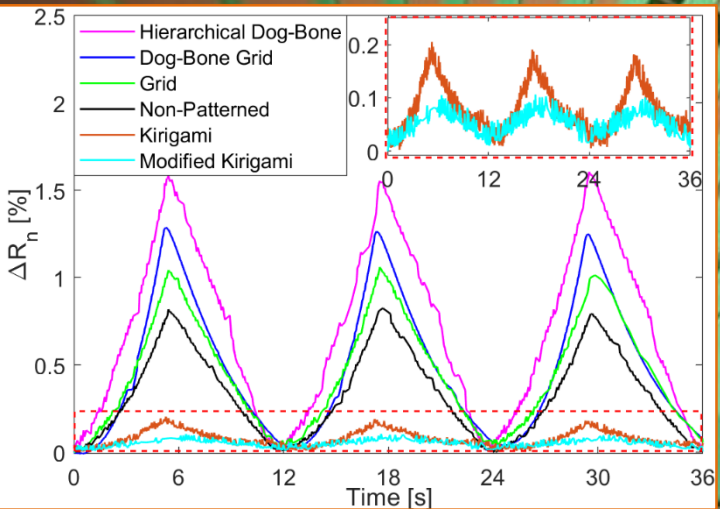
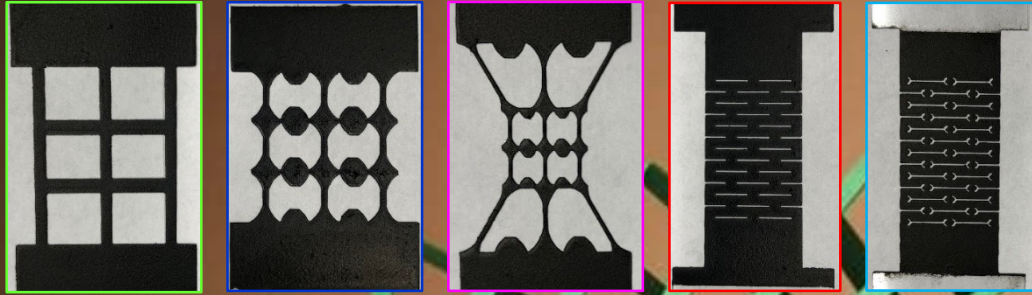
Physiological Monitoring

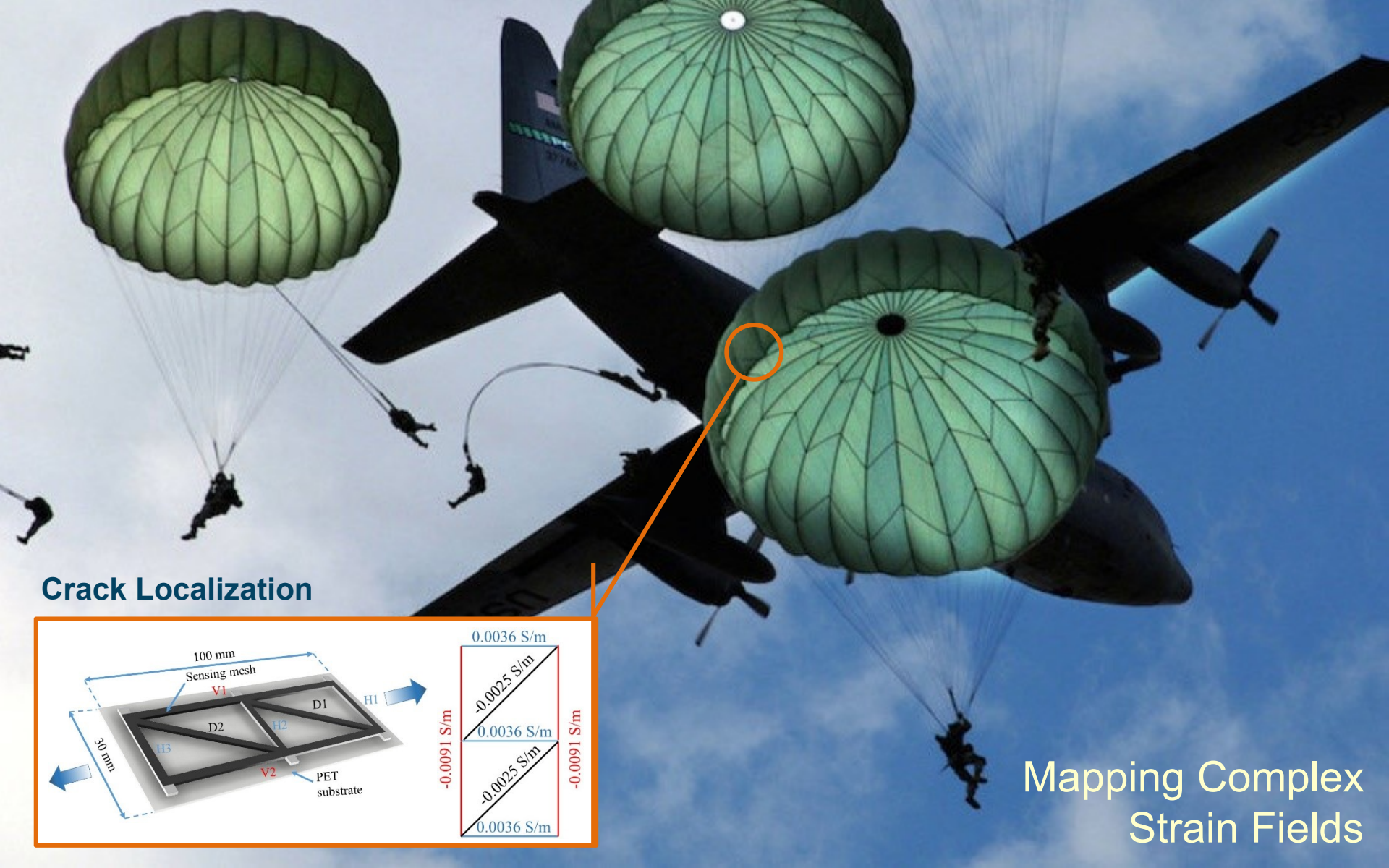


Vitals Monitoring

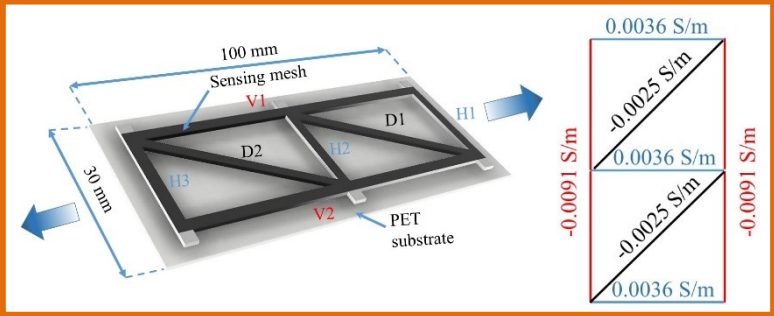


Patterning for Performance



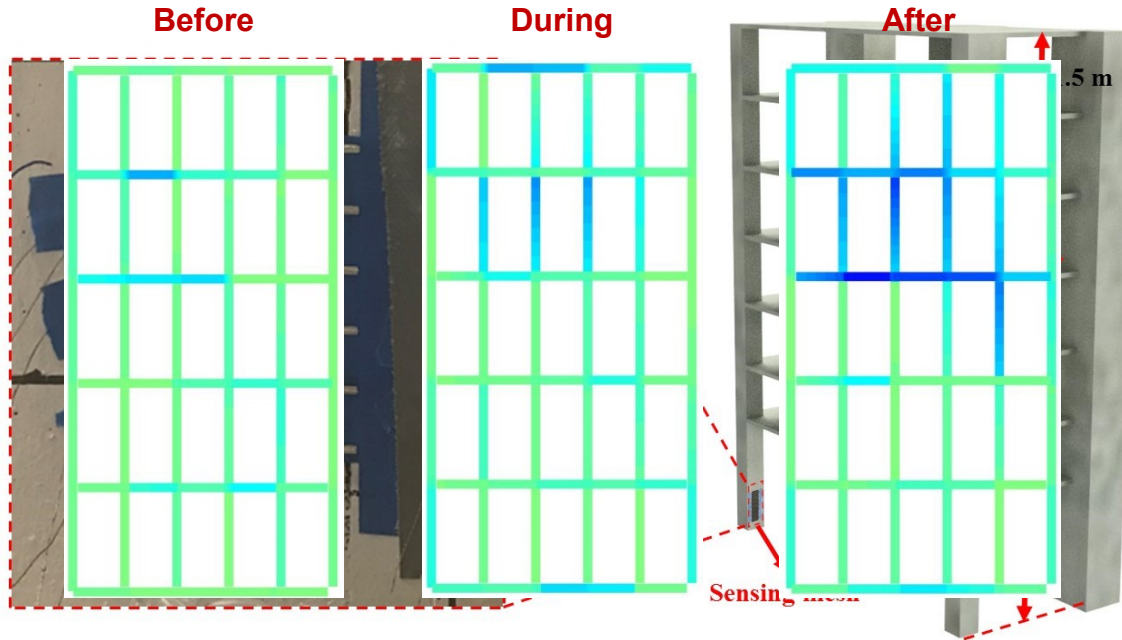


Crack Localization



Mapping Complex
Strain Fields

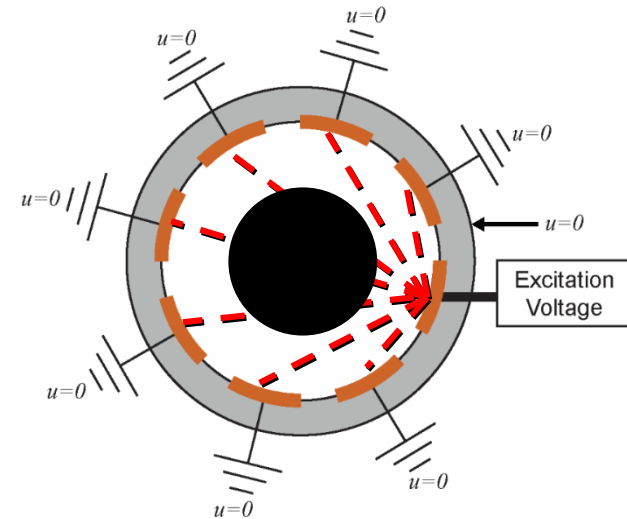
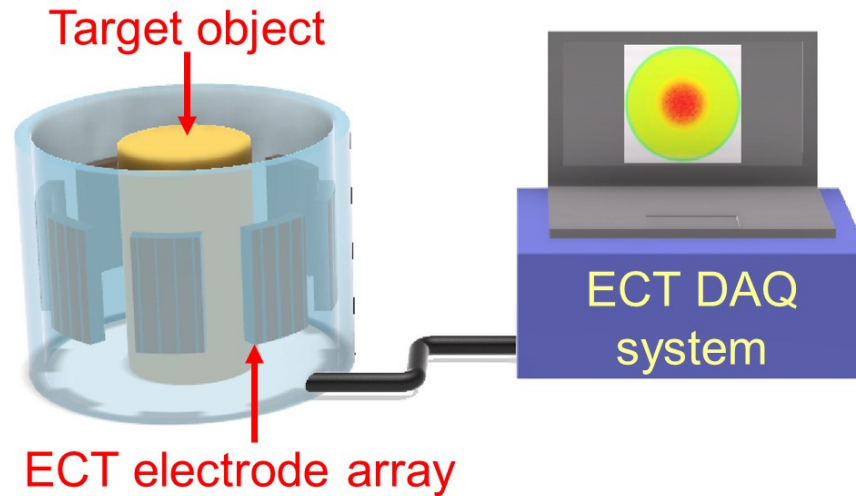
- Sensing mesh instrumented on column of 7-story reinforced concrete building subjected to earthquake ground motion testing
 - ❖ Ground motions increased progressively
 - ❖ Goal: Induce catastrophic structural failure



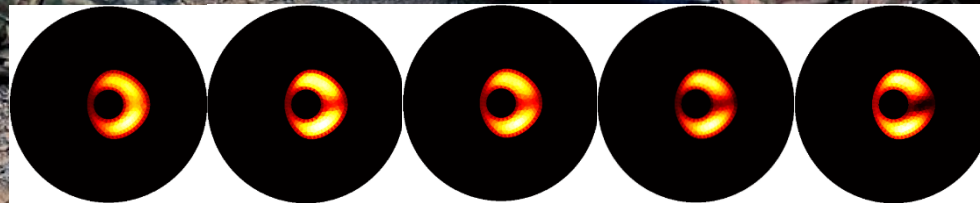
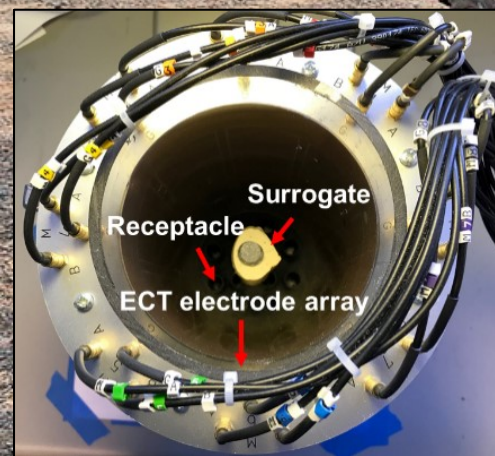
Electrical Capacitance Tomography

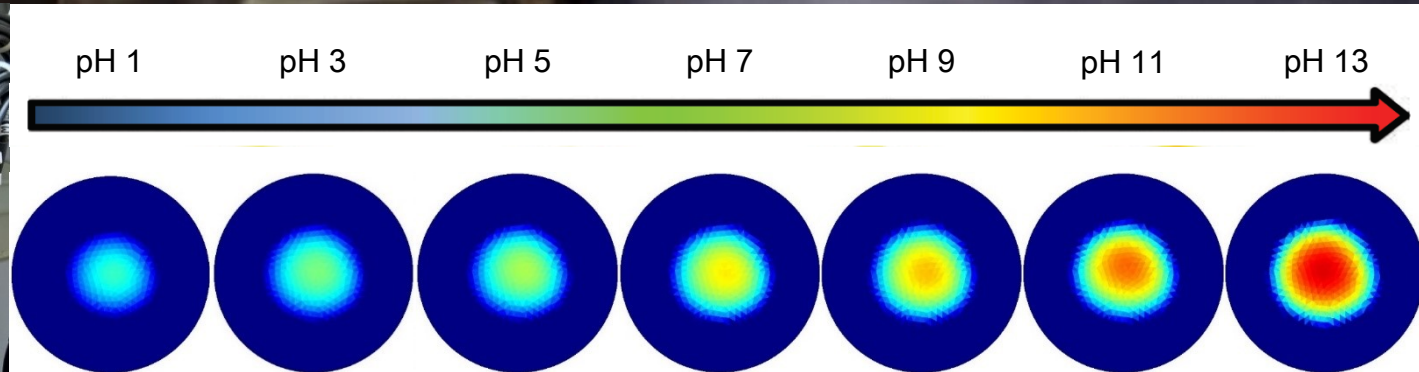


- Soft-field imaging technique that can reconstruct the permittivity distribution using capacitance measurements obtained at boundary

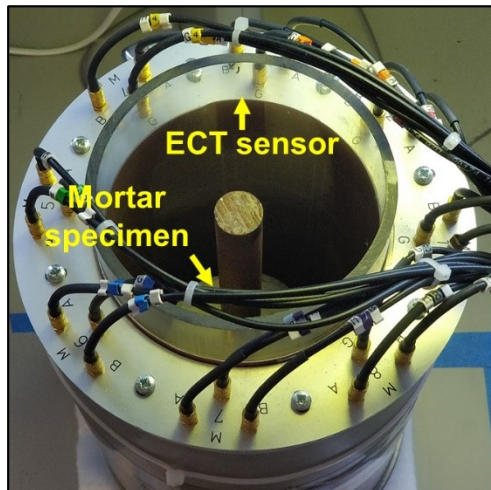
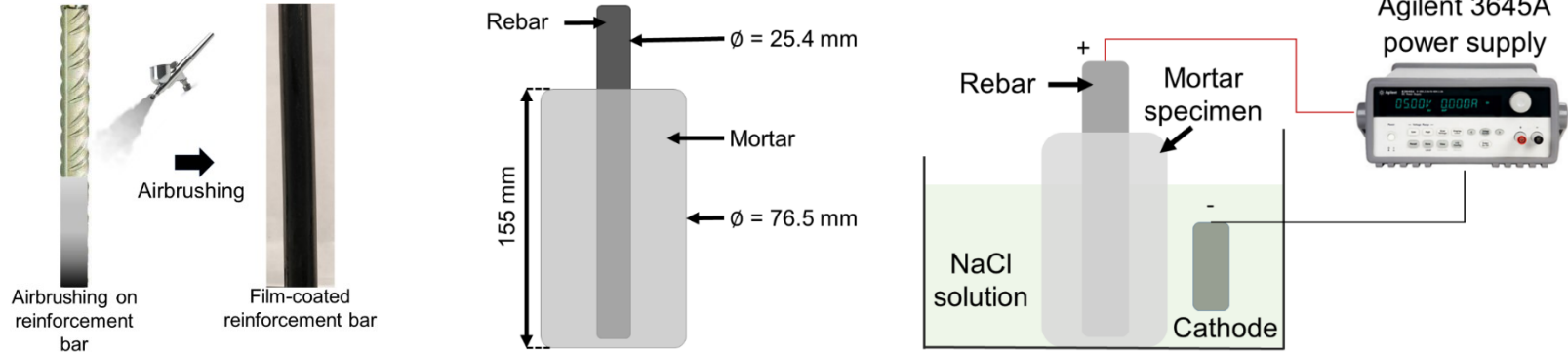


Forward-Deployed Medical Imaging



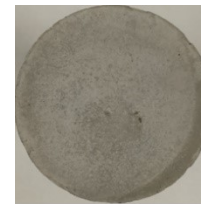


Accelerated corrosion tests performed on mortar cylinder specimens



Corroded specimen

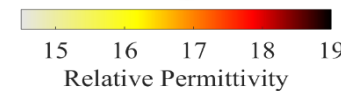
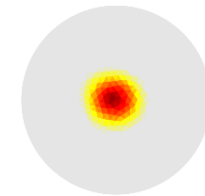
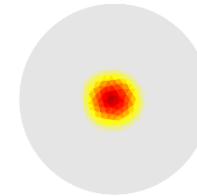
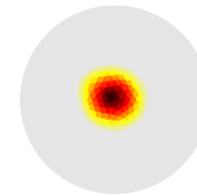
Permittivity maps

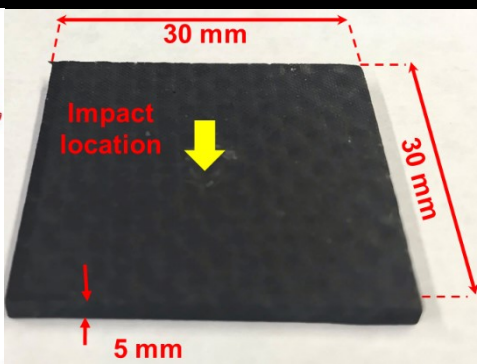
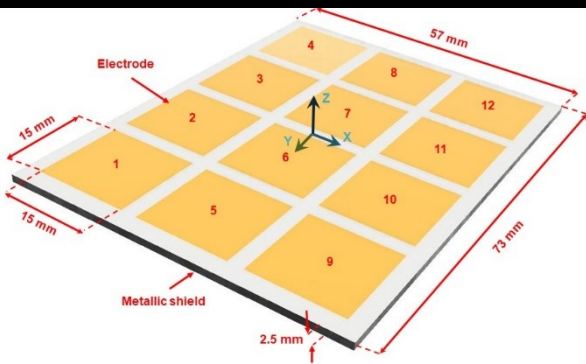


6 h

12 h

18 h

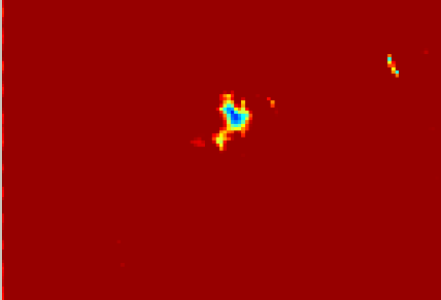




ECT image



C-Scan image



3. Enhancing Warfighter Performance



Flexible Armor

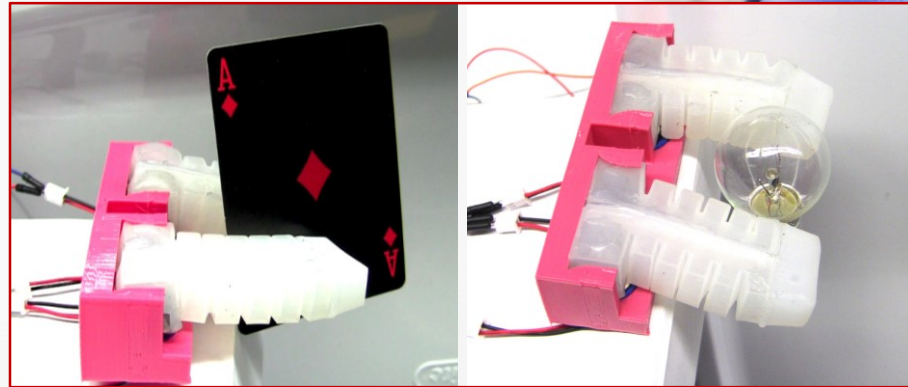
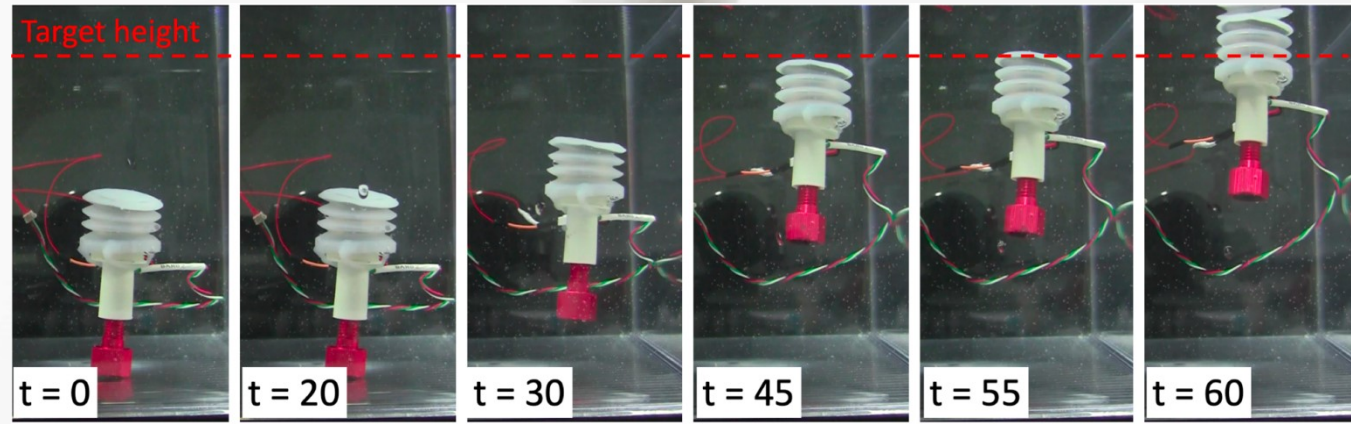
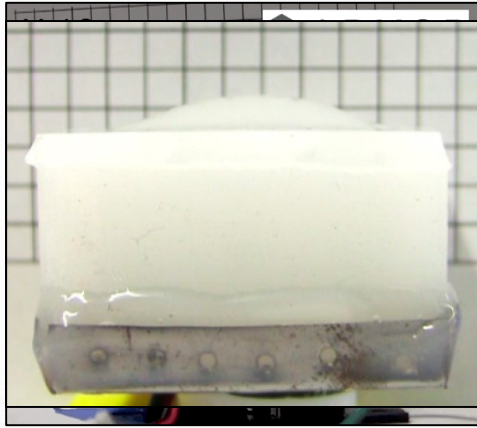
- Additive manufacturing
- **Stimuli-responsive materials**

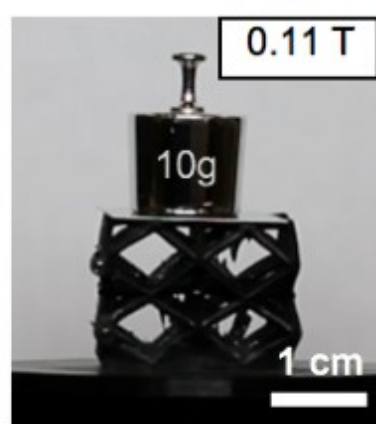
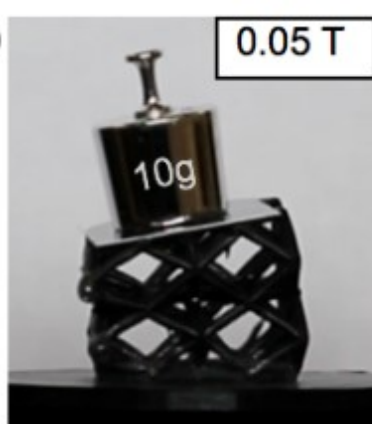
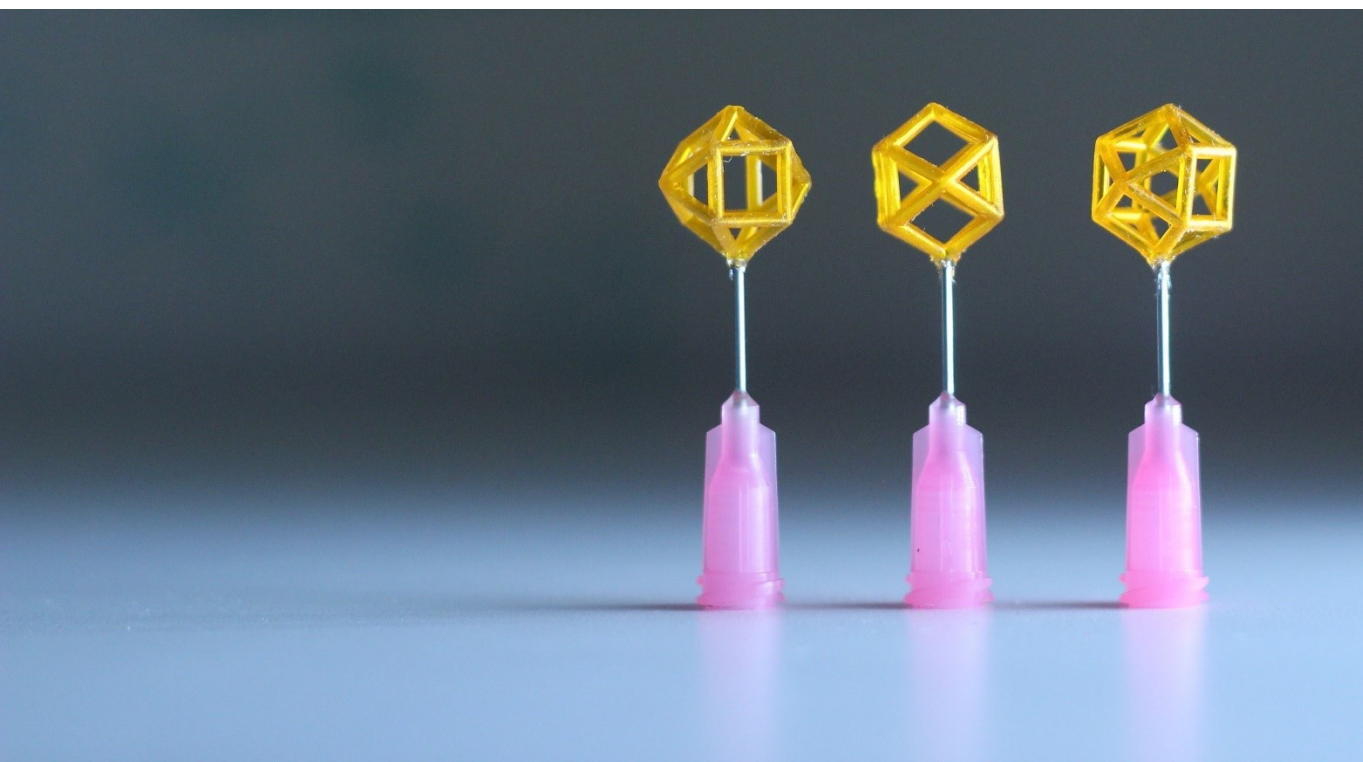
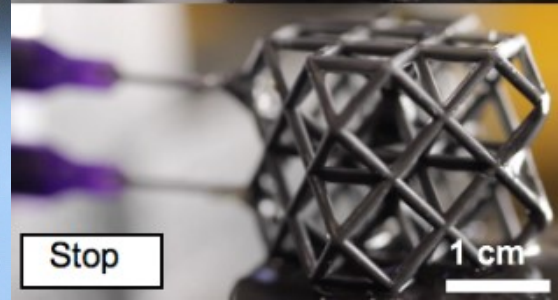
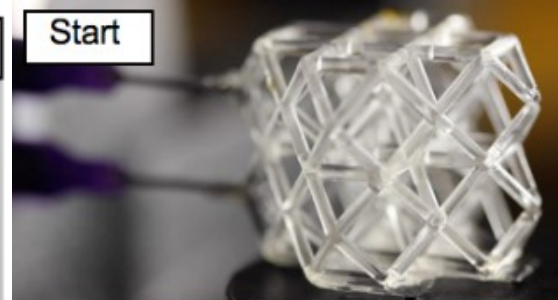


Active Skins

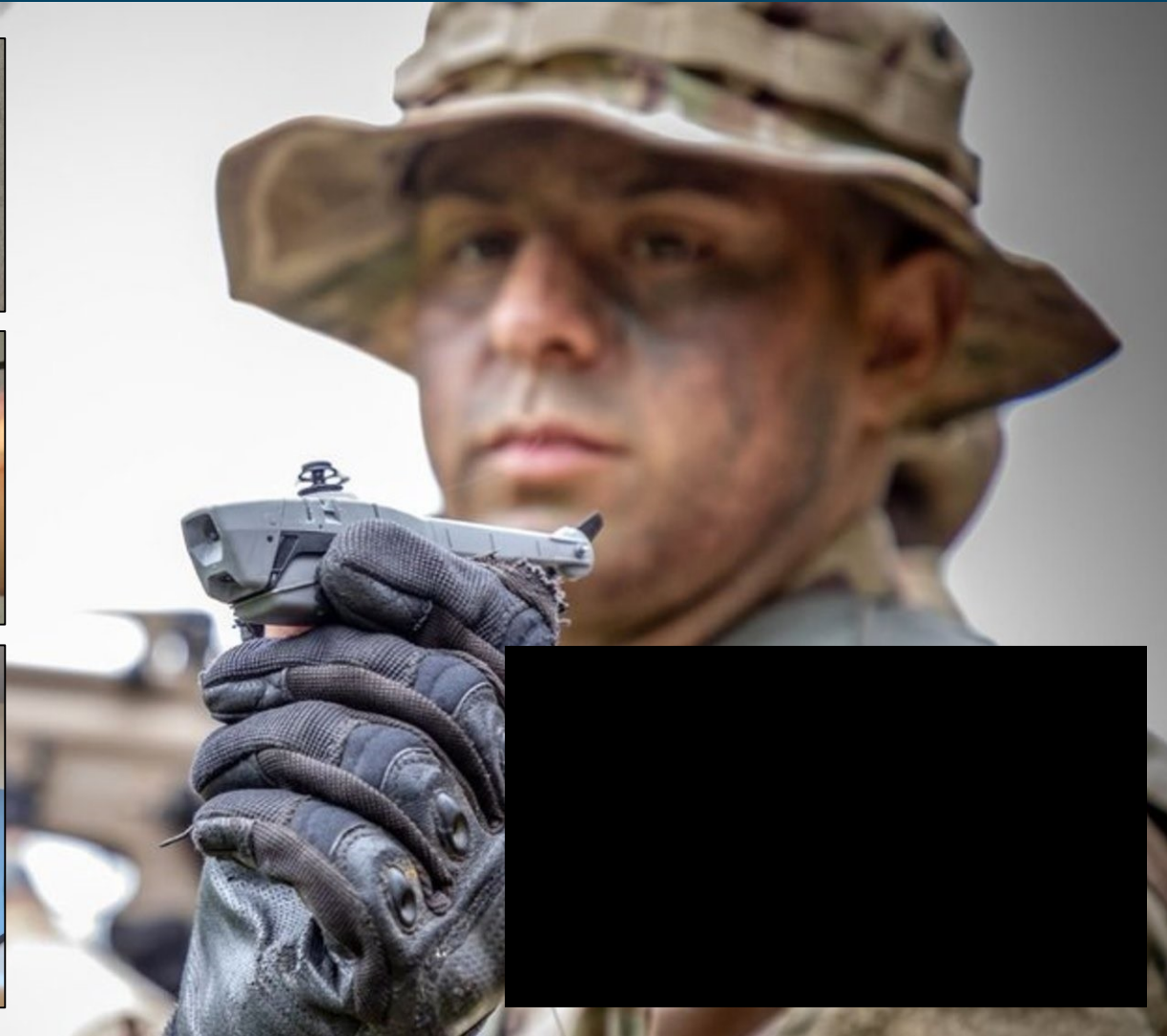
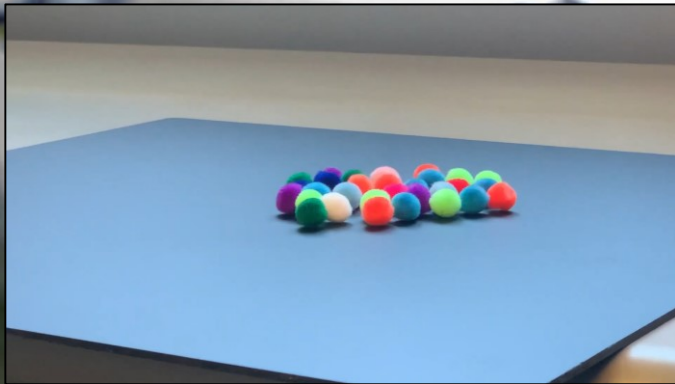
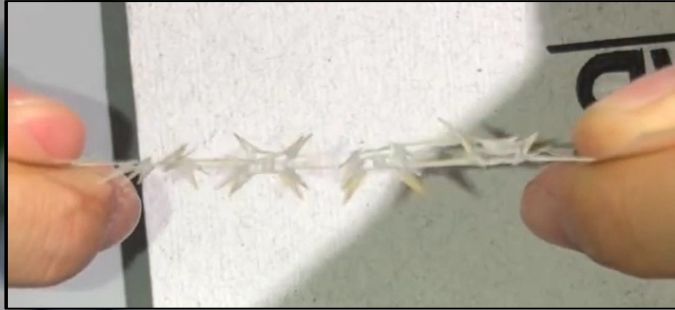
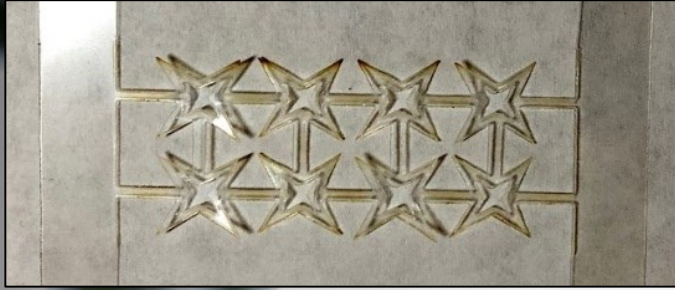
- Unmanned robotic systems
- Adaptable camouflage





C**D****E****Start**

Multifunctional Active Skins (MAS)





Acknowledgements

UNIVERSITY OF CALIFORNIA – SAN DIEGO

Collaborators:



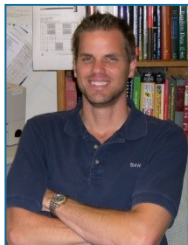
Prof. Wei-Hung
Chiang
NTUST (Taiwan)



Prof. H. Alicia Kim
UC San Diego



Prof. Jerome
Lynch
Univ. of Michigan



Prof. Michael
Todd
UC San Diego



U.S. National Science Foundation (NSF)

Grant Nos. CMMI CAREER-1253564; CMMI-1200521; CMMI-1762530



U.S. Army Corp of Engineers (USACE)

Cooperative Research Agreement No. W912HZ-17-2-0024



U.S. Office of Naval Research (ONR)

Grant Nos. N00014-17-1-2668; N00014-18-1-2483



U.S. Department of Energy (DOE)

Contract No. DE-AC52-07NA27344



U.S. Federal Aviation Administration (FAA)

Cooperative Agreement No. 13-G-017