OVERVIEW OF MECHANICAL ENGINEERING RESEARCH

Auburn University

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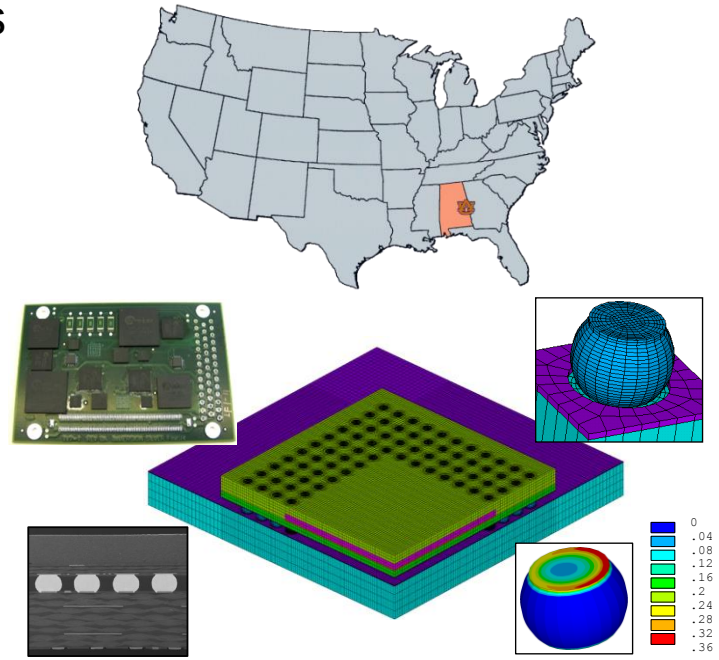
Department of Mechanical Engineering
Auburn University

January 9, 2015
Universidad Austral de Chile, Puerto Montt

OUTLINE

- Mechanical Engineering at Auburn University
  - Undergraduate and Graduate Programs
  - Faculty
  - Research Areas and Spotlights
  - Facilities
- Electronic Packaging Research
  - Material Testing
  - Silicon Sensors and Test Chips
  - Reliability Testing and Modeling




AUBURN UNIVERSITY
INSTRUCTION
RESEARCH
EXTENSION
FOR THE
ADVANCEMENT
OF SCIENCE
AND ARTS
ESTABLISHED 1856

AUBURN ENGINEERING

AUBURN ENGINEERING

Enrollment

- 4100+ Undergraduate
- 850+ Graduate Students

Programs

- 13 Undergraduate Programs in 8 Departments
- Masters and Doctoral Degrees
- 140+ Faculty
- Ranked 28th Overall in the USA in Engineering

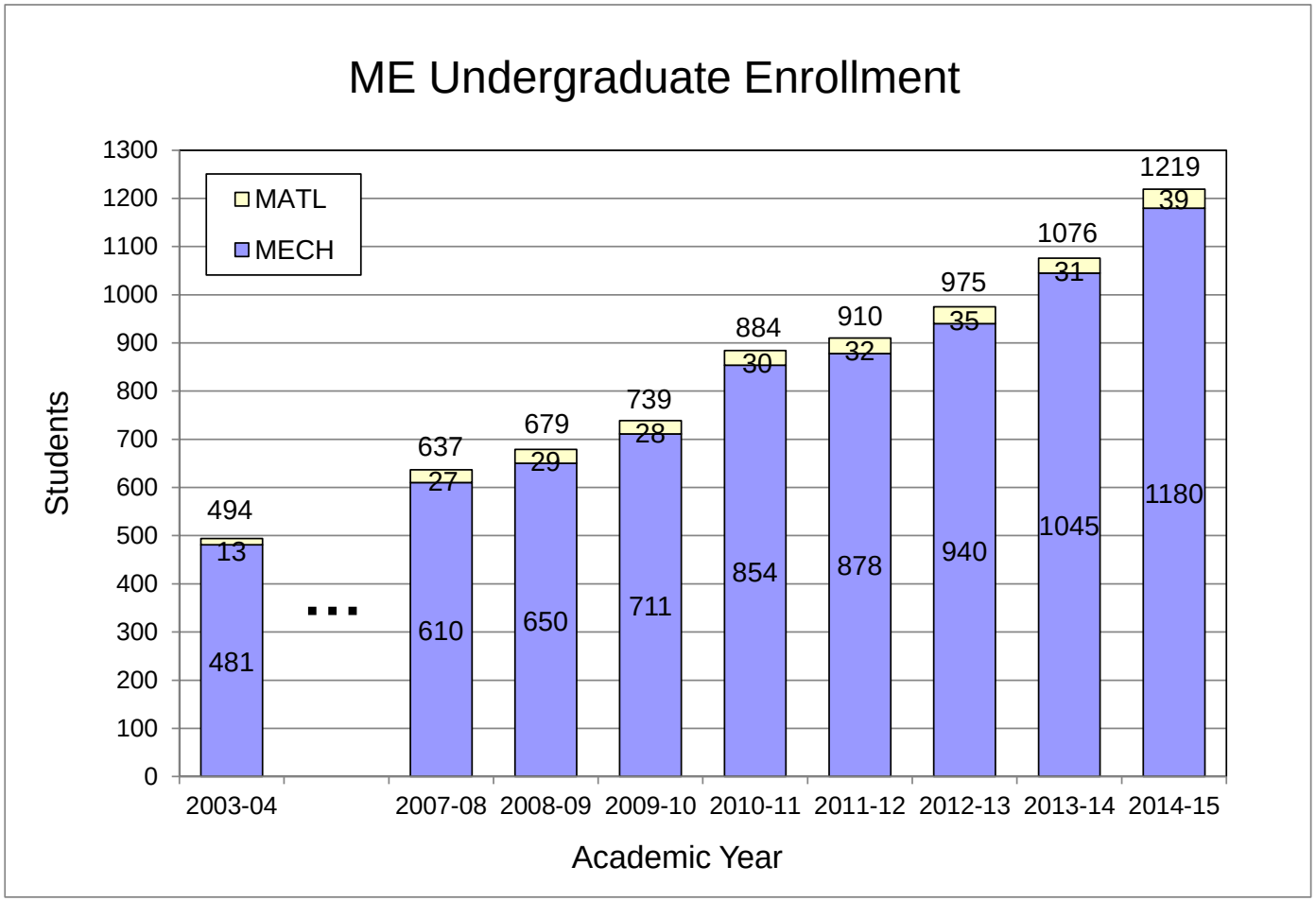
AUBURN ENGINEERING

Accreditation and Rankings

- ABET Accredited
- Ranked 28th Overall in the USA in Engineering

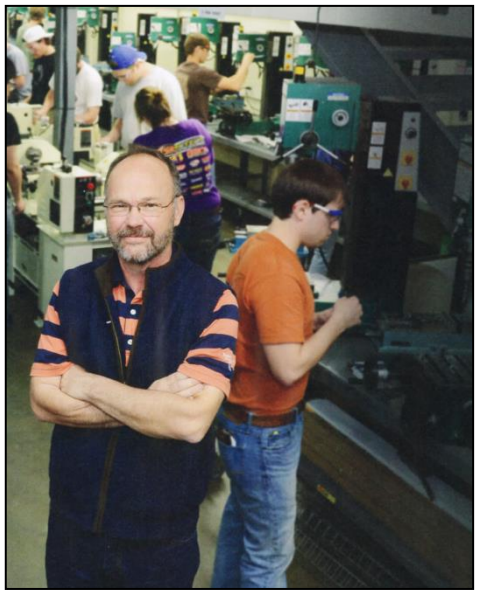
UNDERGRADUATE PROGRAM

Auburn University Mechanical Engineering



PROGRAM SPOTLIGHT

Design and Manufacturing Laboratory



PROGRAM SPOTLIGHT

War Eagle Motorsports

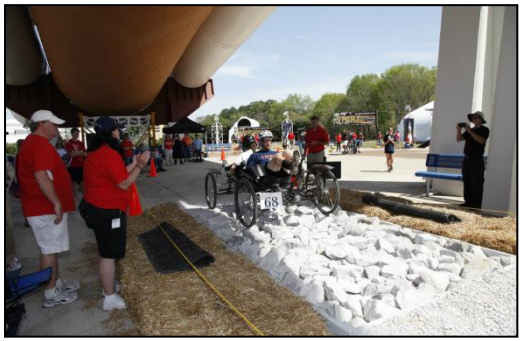
FORMULA SAE ELECTRIC

NASA ROVER COMPETITION

MSFC, Huntsville, AL, April 2014

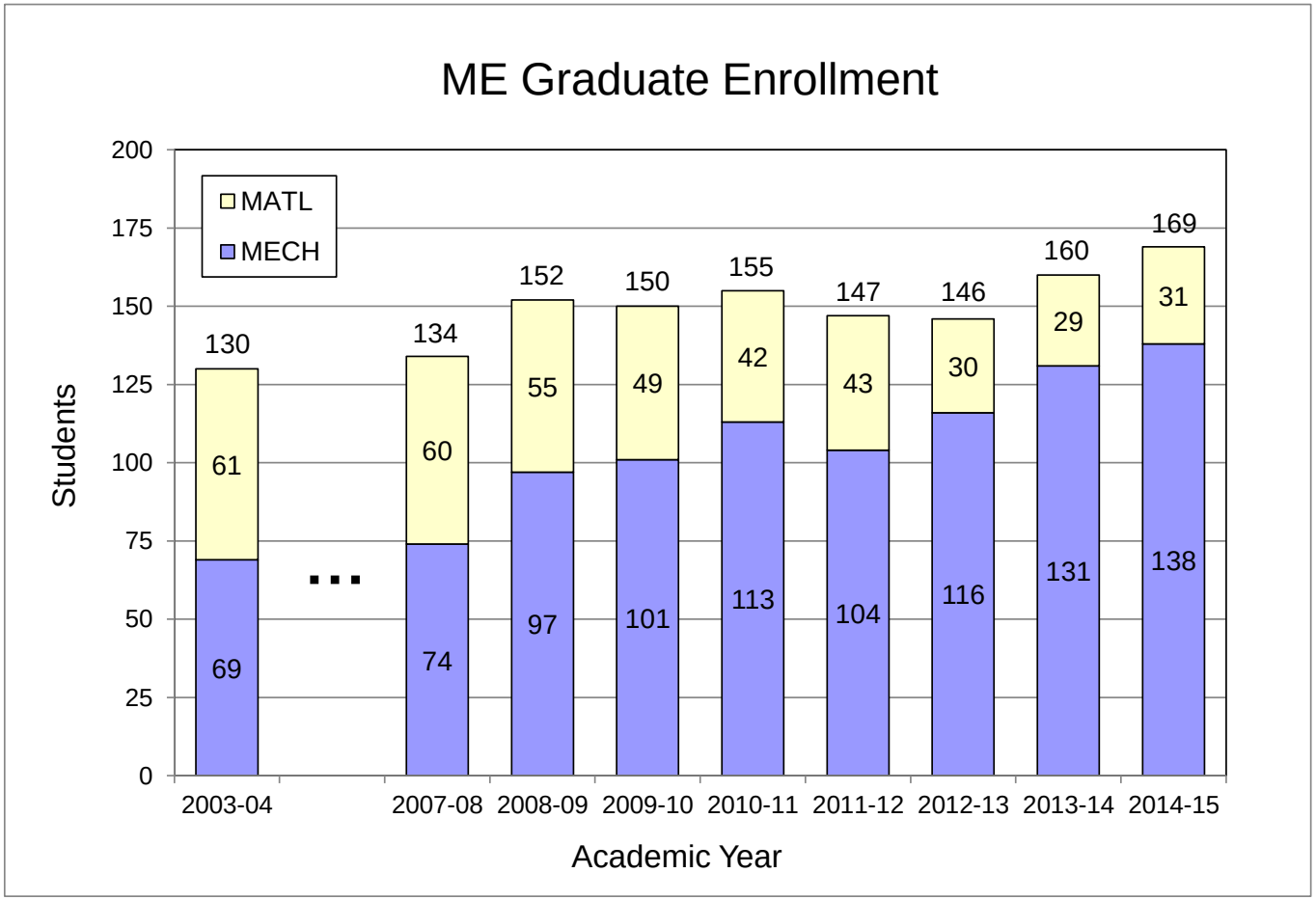
NASA Human Exploration ROVER CHALLENGE

4th Place out of 46 Teams



GRADUATE PROGRAM

Auburn University Mechanical Engineering



GRADUATE DEGREES

AU Mechanical Engineering

- Master of Science (M.S.) (Non-Thesis)
  - 30 Credit Hours of Course Work [1.0-2.0 Years]
- Master of Science (M.S.)
  - 24 Credit Hours of Course Work [1.0-1.5 Years]
  - 6 Credit Hours of Research Based Thesis [1.0-1.5 Years]
  - Funding from Graduate Assistantship [$1000-$2000 per month]
- Doctor of Philosophy (Ph.D.)
  - 30 Hours of Course Work [1.0-2.0 Years]
  - 30 Credit Hours of Research Based Dissertation [1.0-3.0 Years]
  - Funding from Graduate Assistantship [$1000-$2000 per month]

FACULTY

Department of Mechanical Engineering


Abdel-Hadi


Ayasoufi


Baumann


Beale


Bevly


Bhavnani


Burch


Cheng


Chin


Choe


Crocker


Dyer


Falkenberg


Fergus


Flowers


Harris


Jackson


Jones


Kang


Khodadadi


Kim


Knight


Lall


Mackowski


Madsen


Marghitu


Mishra


Overfelt


Payton


Prorok


Ragan


Raju


Roberts


Simonian


Sinha


Suhling


Thakur


Tippur


Williams


Zee

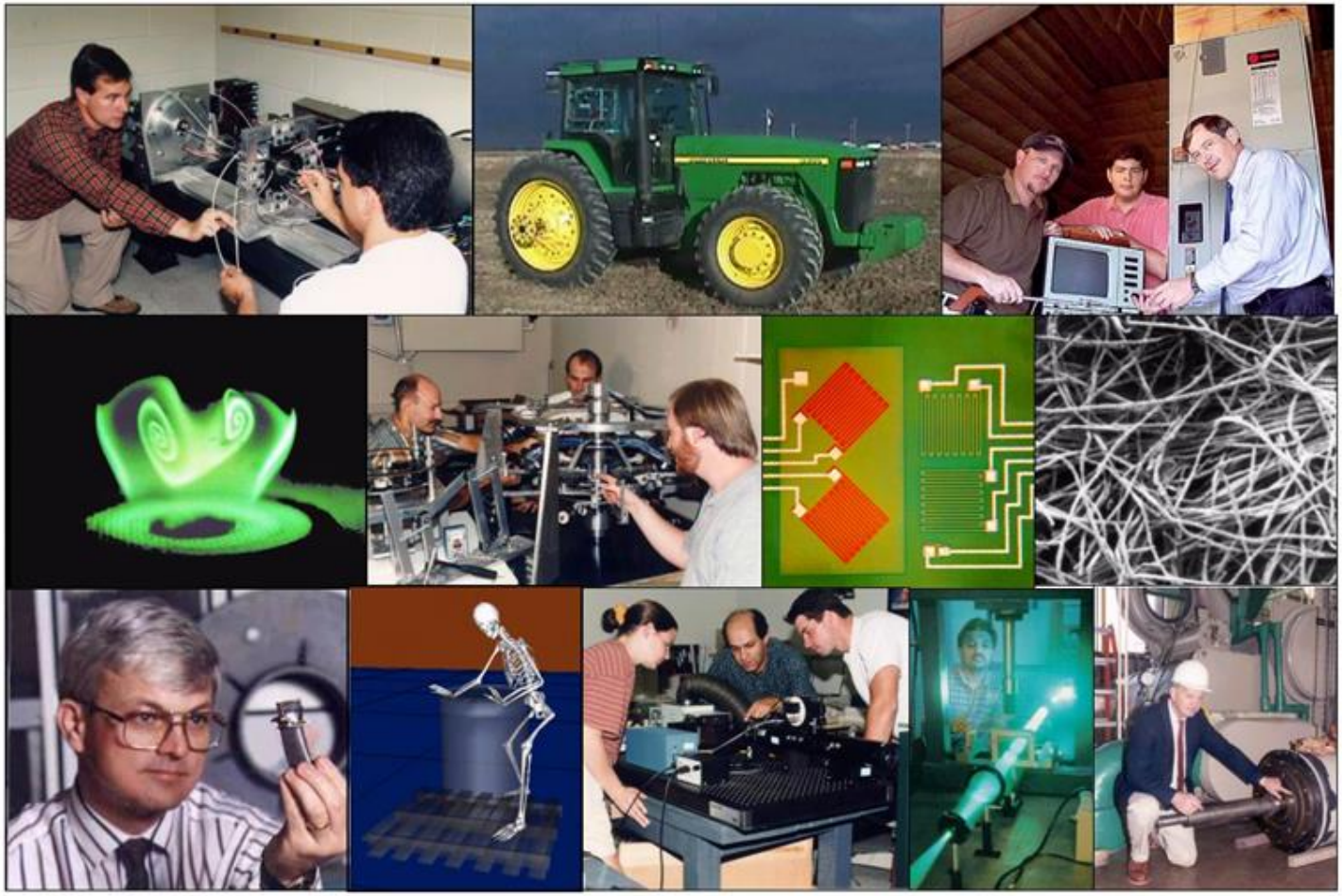
FACILITIES

AU Mechanical Engineering

Wiggins Hall (Mechanical Engineering, and
Woltosz Advanced Engineering Research Laboratories

RESEARCH AREAS

AU Mechanical Engineering



RESEARCH AREAS

AU Mechanical Engineering

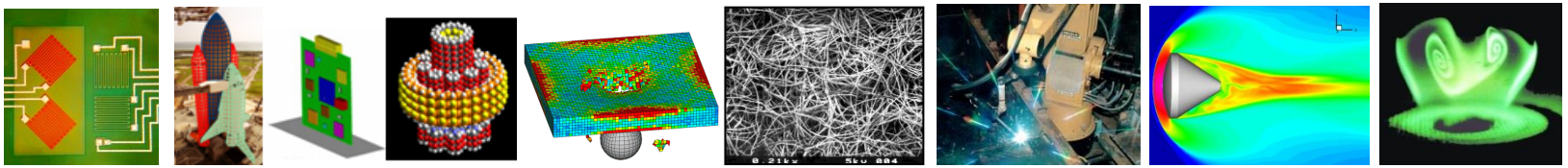
- Acoustics
- Advanced Powertrains
- Automotive Design
- Biohazard Detection
- Biomechanics
- Casting
- CFD
- Coatings and Thin Films
- Combustion
- Composite Materials
- Design of Machinery
- Dynamic Stability
- Electrical Connectors
- Electronics Cooling
- Electronic Packaging
- Electro-Optics
- Energy Harvesting Devices
- Energy Storage Devices
- Energy Sustainability
- Experimental Mechanics
- Finite Element Analysis
- Fluid Mechanics
- Flywheels
- Food Safety
- Fracture Mechanics
- Fuel Cells
- Gas Turbines
- GPS Guidance and Control
- Graded Materials
- Heat Pipes
- Heat Transfer
- HVAC
- Impact Dynamics
- Interferometry
- Magnetic Bearings
- Materials Processing
- MEMS
- Microfluidics/Nanofluidics
- Microscopy
- Motion Analysis
- Nanotechnology
- NDT/NDE
- Noise Control
- Nonlinear Optics
- Nonlinear Systems
- Optical Metrology
- Organic Semiconductors
- Prognostics (PHM)
- Radiation
- Robotic Welding
- Robotics
- Rotor Dynamics
- Sensors (Biological)
- Sensors (Chemical)
- Sensors (Magnetostrictive)
- Sensors (MEMS)
- Sensors (Piezoelectric)
- Sensors (Piezoresistive)
- Smart Materials
- Solar Energy
- Sound and Vibration
- Test Chips
- Thermal Systems
- Tribology
- Unmanned Vehicles (UAV)
- Vehicle Stability Control

RESEARCH AREAS

AU Mechanical Engineering

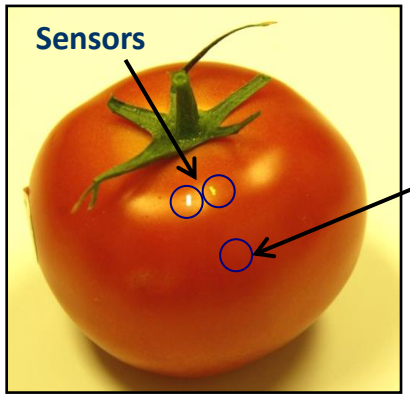
ME Department 2014
Annual Research
Funding: US$ 6M
Publications: 250

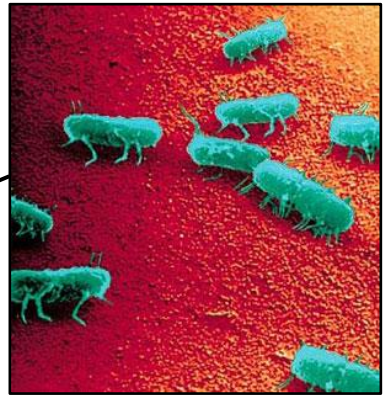
- Research Thrusts
  - **Materials** (Sensors, Bio/Nano, Detection and Food Safety)
  - **Electronic Packaging** (Reliability in Harsh Environments)
  - **Vehicle Technology** (Unmanned/Autonomous; Dynamics, Stability, and Controls; Advanced Powertrains: Fuel Cell and Hybrid)
- Research Centers
  - MREC (Materials Research and Education Center)
  - AUDFS (Auburn University Detection and Food Safety Center)
  - ACER (Air Cabin Environmental Research)
  - CAVE^3 (Center for Advanced Vehicle and Extreme Environment Electronics)
- Research Center in Development
  - NSF STC on Next Generation Detection Technologies for Societal Health and Environment (Simonian, et al.)



RESEARCH SPOTLIGHT

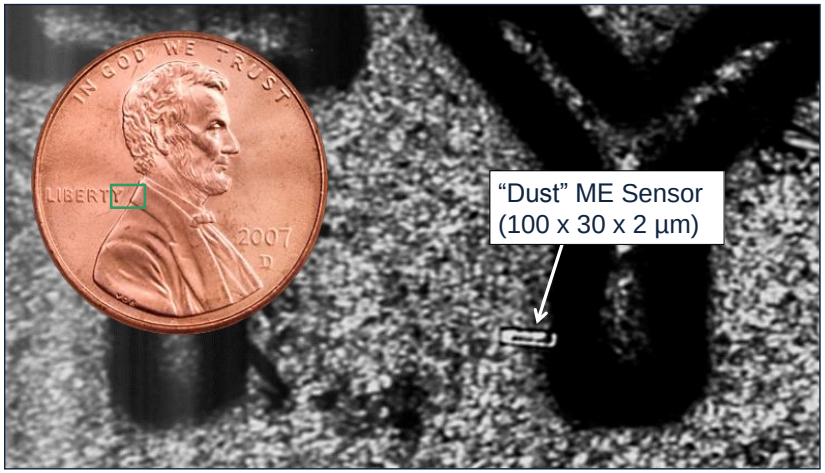
AUDFS - Research in Biosensing of Pathogens and Food Safety



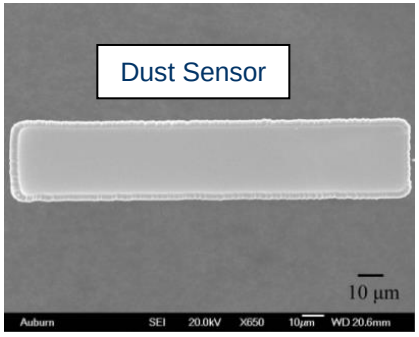


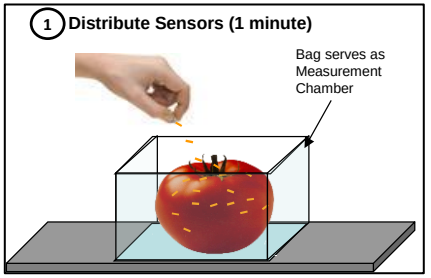
Dust Sensors

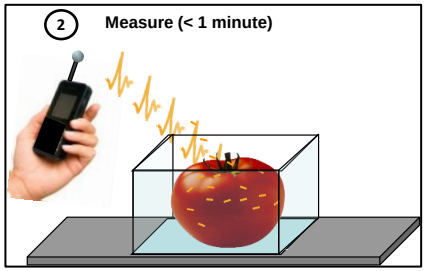
A Newly Developed and Patented Sensing Technology Enabling the Wireless, In-field Detection of Bacteria on Fresh Produce.

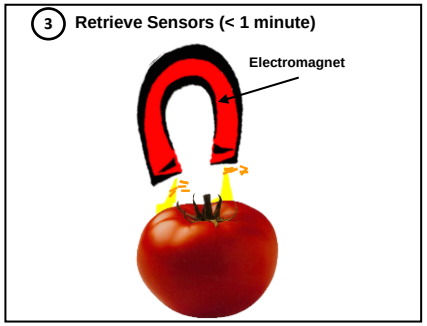


AUBURN UNIVERSITY
DETECTION AND FOOD SAFETY CENTER









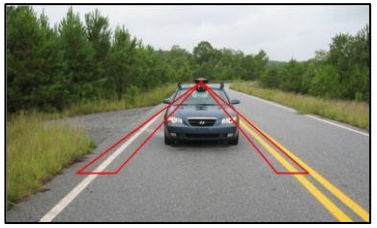
RESEARCH SPOTLIGHT

Research on Autonomous Vehicles and Vehicle Dynamics/Control

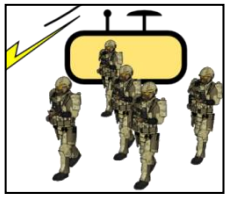
David Bevly, PI
$15M Research over Past 10 Years
Currently 26 Students (8 PhD, 14 MS, 4 BS)

<u>Example Research Topics</u>

- Unmanned Autonomous Vehicles
- Vehicle modeling
- Determination of rollover propensity
- Vehicle sensor fusion/integration
- GPS/INS navigation
- IMU & laser scanner fusion
- Sensor characterization and modeling
- Development of a software GPS receiver
- High speed control of ground vehicles



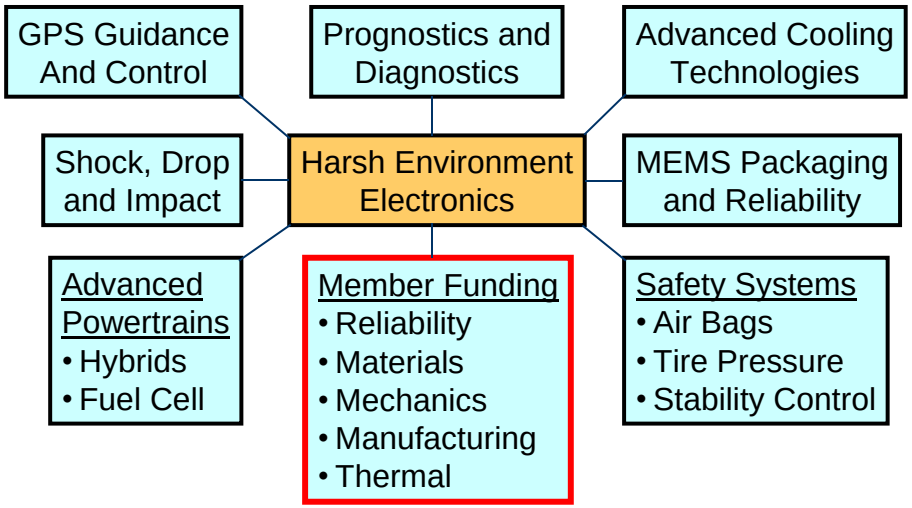
GAVLAB



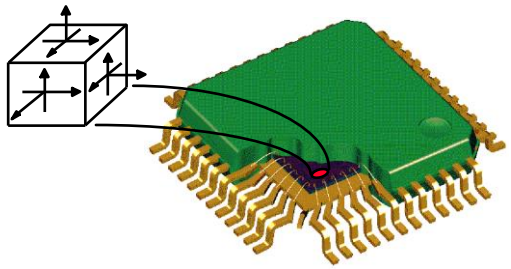
RESEARCH SPOTLIGHT

CAVE^3 - Center for Advanced Vehicle & Extreme Environment Electronics

- A National Science Foundation Industry/University Cooperative Research Center (I/UCRC)
- Objective: Research and Development (in Collaboration with Industry) on Electronic Packaging in Harsh Environments
- Demographics:
  - 20 Member Companies
  - 15 Faculty, 5 Staff
  - 35 Graduate Students
  - 10 Laboratories



Director: Pradeep Lall
E-mail: lallpra@auburn.edu



RESEARCH OVERVIEW

Electronic Packaging

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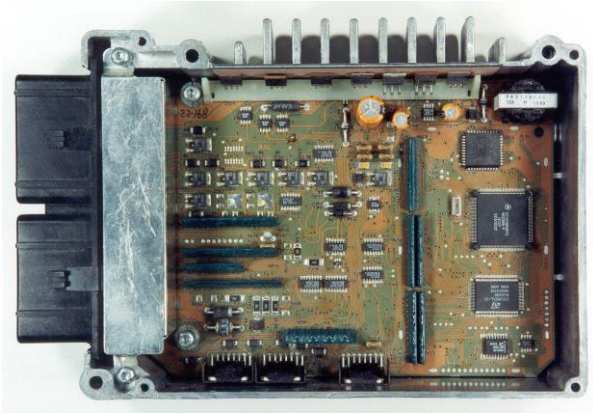
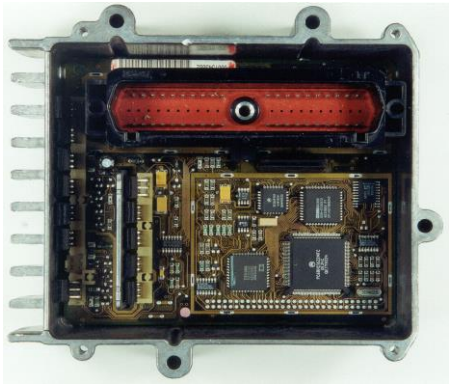
ELECTRONIC PACKAGING

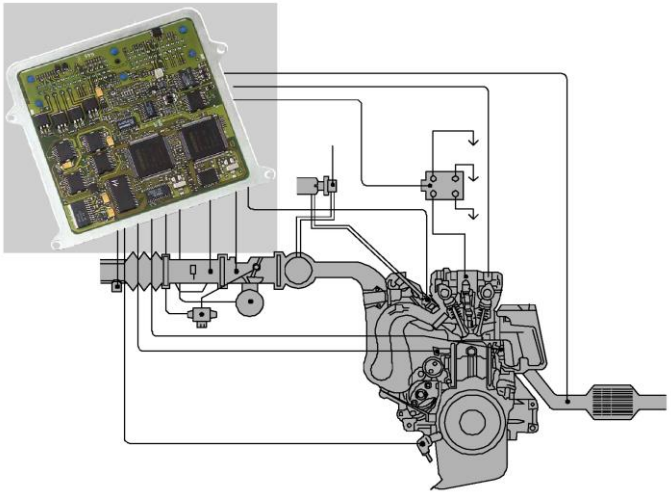
Example IPhone 6

ELECTRONIC PACKAGING

Example - Engine Controllers

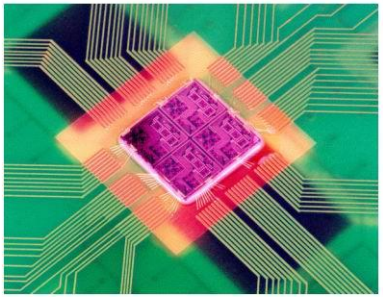


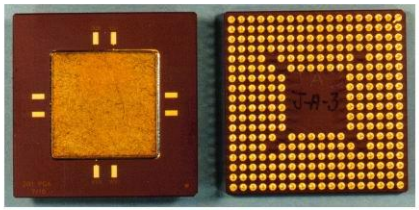


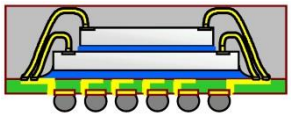


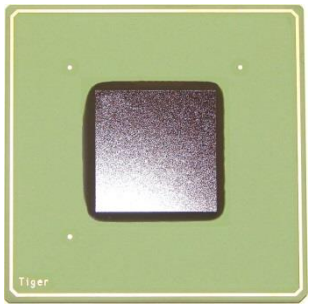
ELECTRONIC PACKAGING

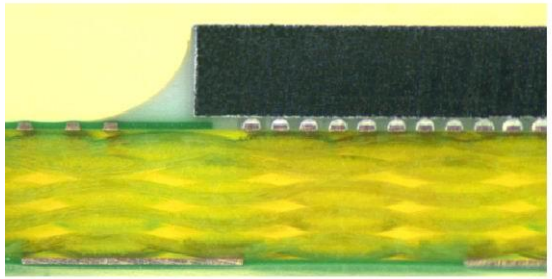
Examples from Auburn Stress Sensor Research

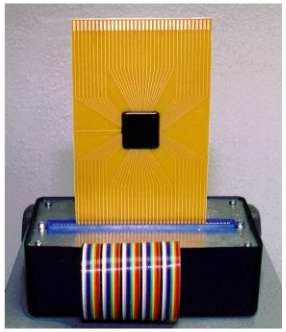


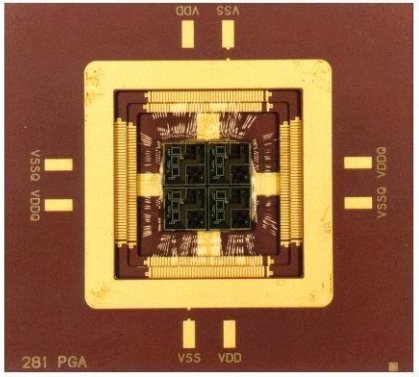


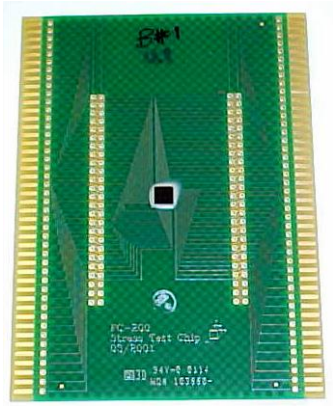


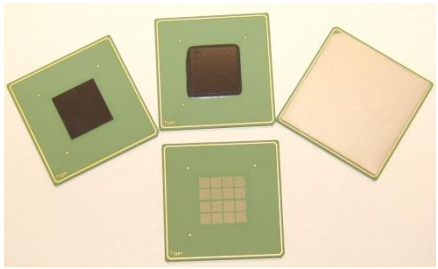


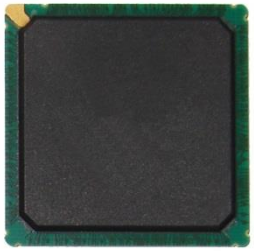


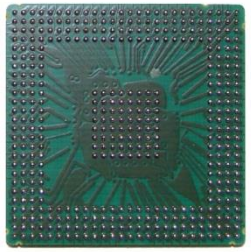


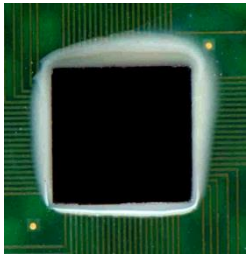










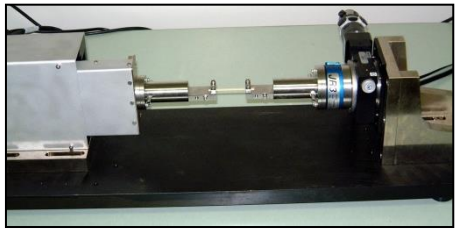


RESEARCH AREAS

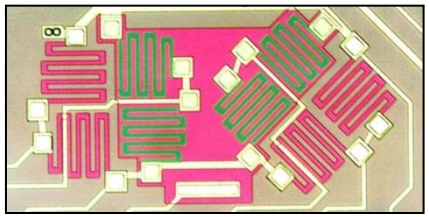
Suhling Research Group

General Areas:
Solid Mechanics
Stress Analysis

- Characterization and Modeling of the Mechanical Behavior of Microelectronic Packaging Materials
  - Materials: Solders, Underfills, Mold Compounds, Adhesives, TIMs, Ceramics, PCBs, etc.
  - Tests: Stress-Strain (Tension/Compression/Shear) Creep, Poisson's Ratio, DMA, TMA, CTE, etc.
  - Constitutive Model Development
  - Aging Effects (Exposure to Temperature/Humidity)



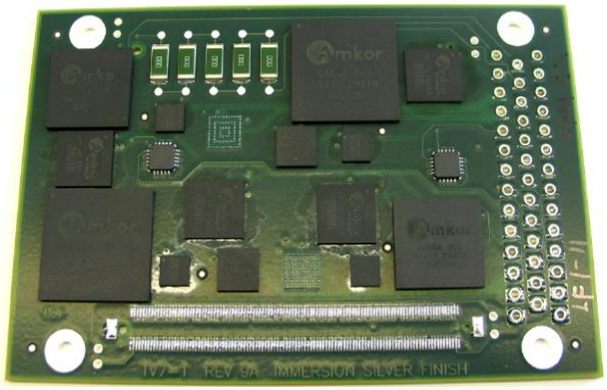
- Silicon Piezoresistive Stress Sensors and Test Chips for Assembly and Reliability Studies
  - Sensor Theory and Calibration
  - Applications to Various Packaging Configurations

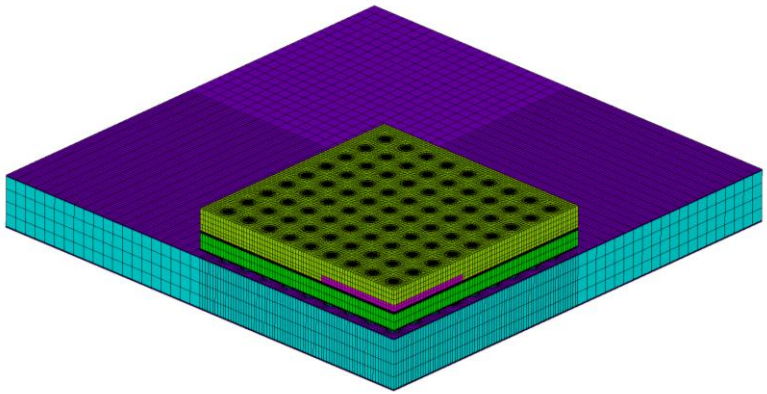


RESEARCH AREAS

Suhling Research Group

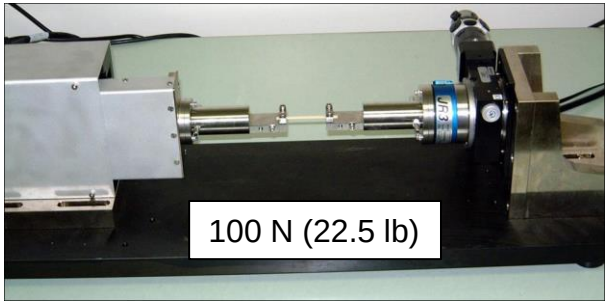
- Reliability Testing and Modeling
  - Experimental: Thermal Cycling, Thermal Shock, MSL/Humidity of Test Assemblies
  - Modeling: Finite Element Predictions for Thermal Cycling and Mechanical Loading



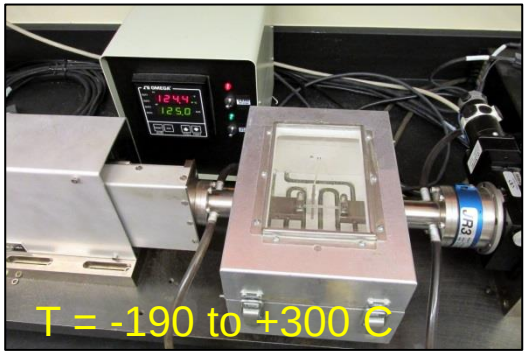


Capabilities

Mechanical Testing (Small Specimens)



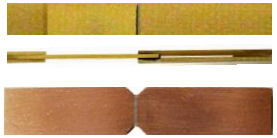
5 kN (1125 lb)

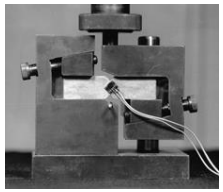


- Tension/Torsion
- Stress-Strain
- Creep
- Shear
- Fatigue
- Poisson's Ratio
- DMA, TMA, DSC

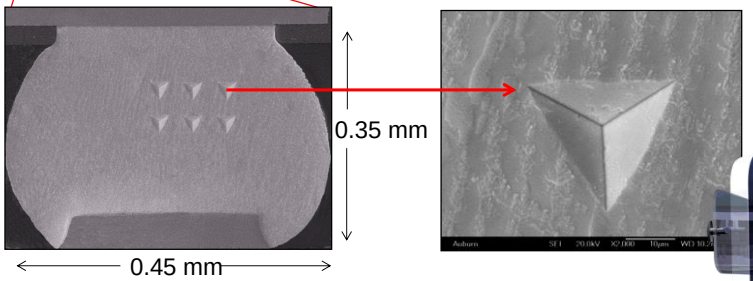
1 kN (225 lb)

5 kN (1125 lb)



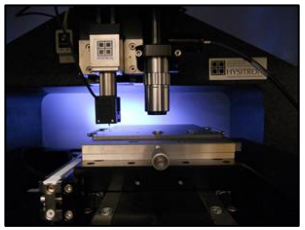


Nanoindentation



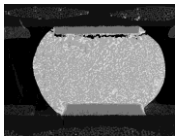
New System ($500K)

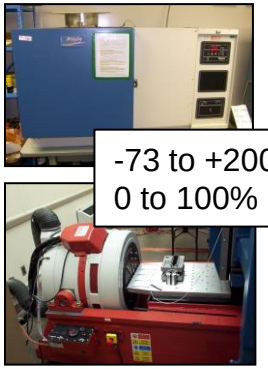
- Dual Head
- Temperature
- Humidity



Environmental Testing

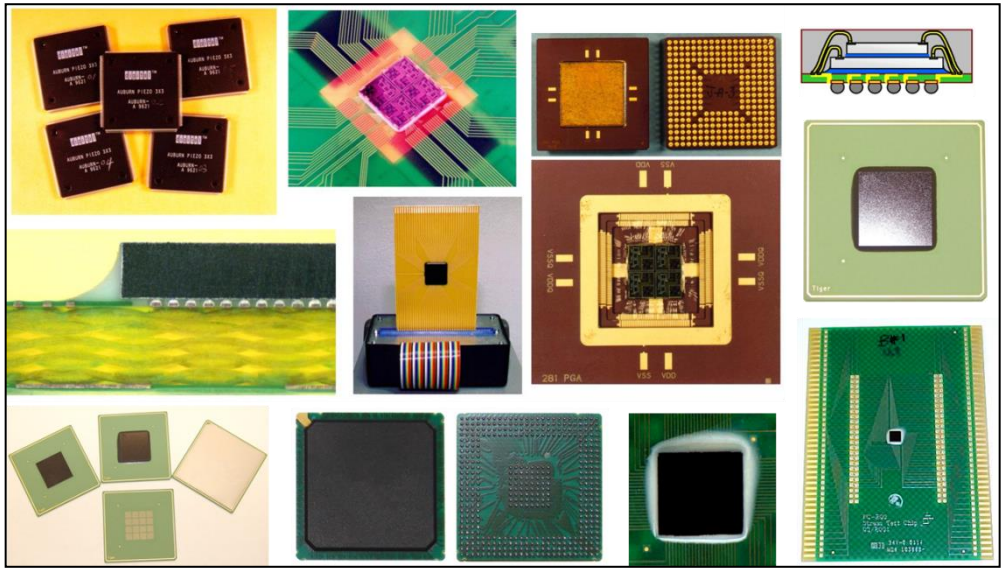
- Thermal Cycling and Thermal Shock
- Temperature, Humidity, Vibration



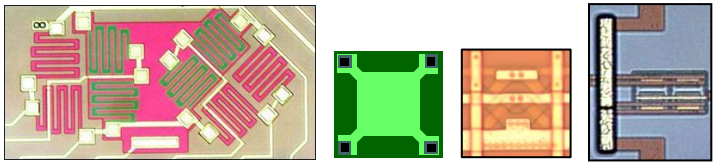


Capabilities

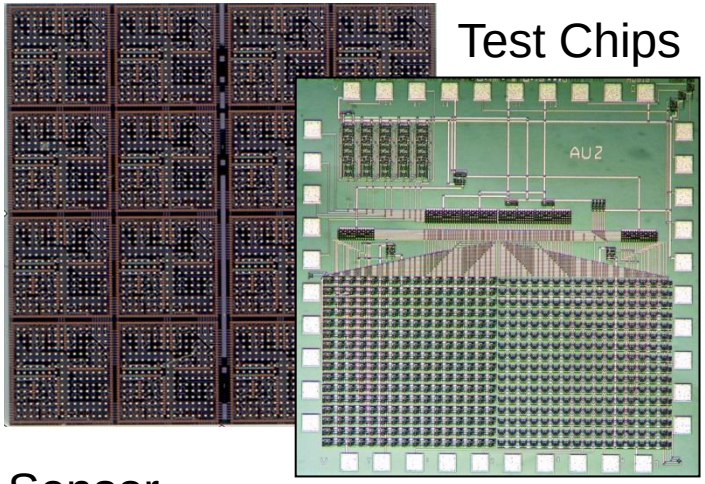
Advanced Electronic Packaging



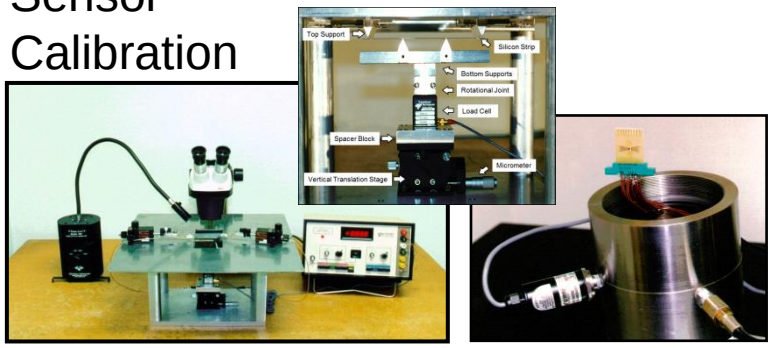
Silicon Sensors



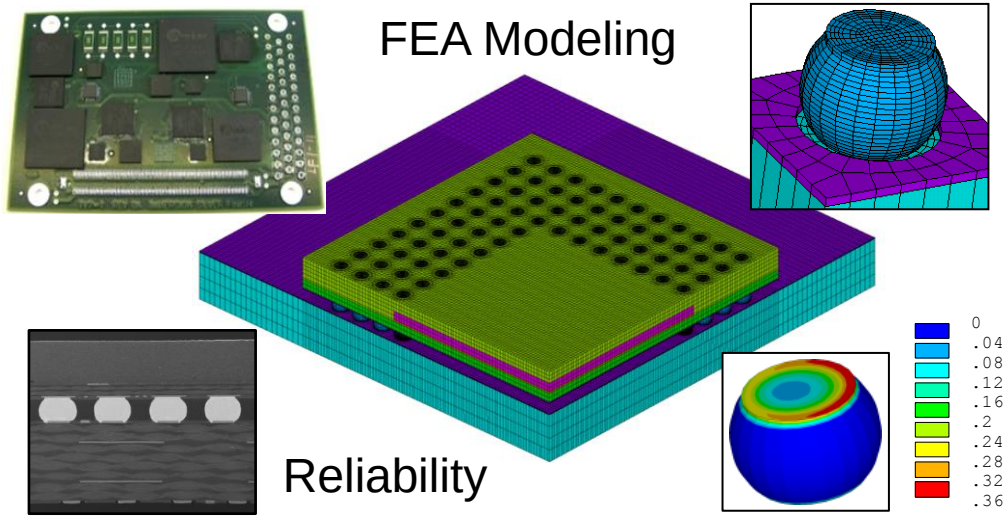
Test Chips



Sensor Calibration



FEA Modeling

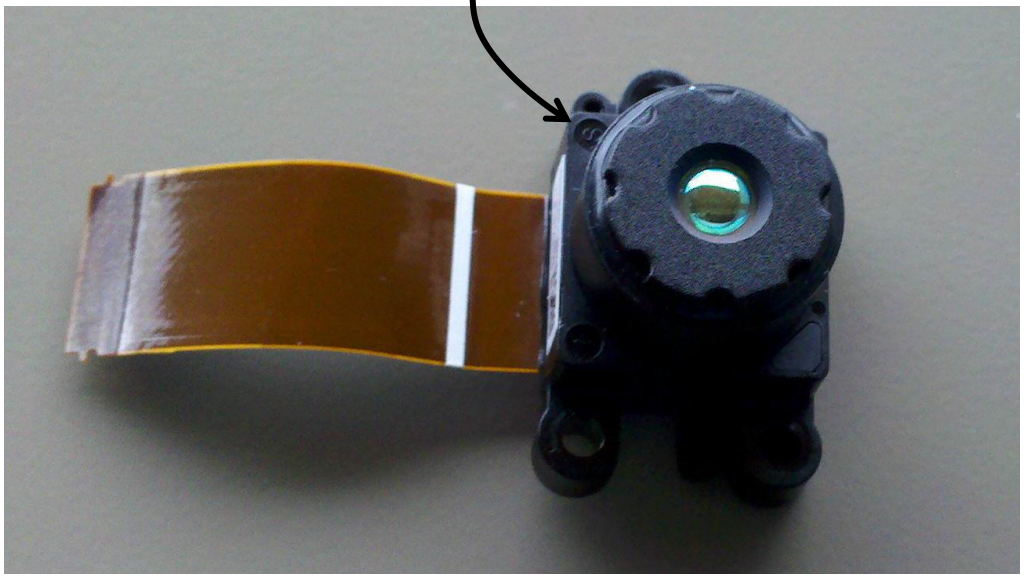


Reliability

MICROSOFT APPLICATION

Polycarbonate Material in Kinect Camera Housing

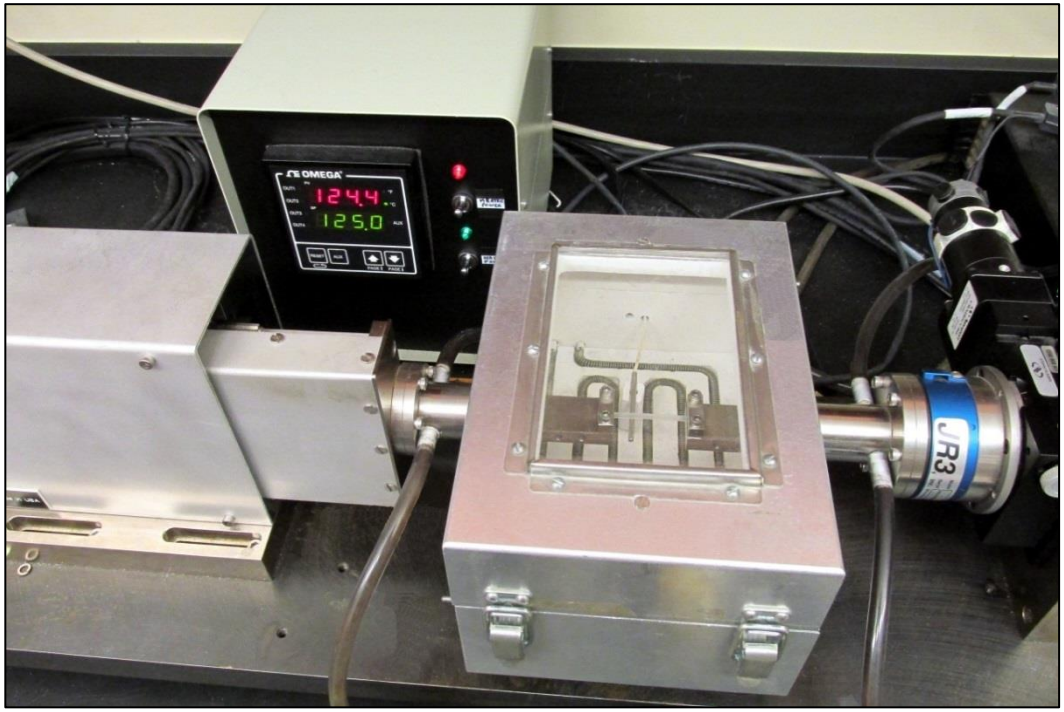
Kinect Operating Temperature Near Camera Module is Approximately T = 60-65 C

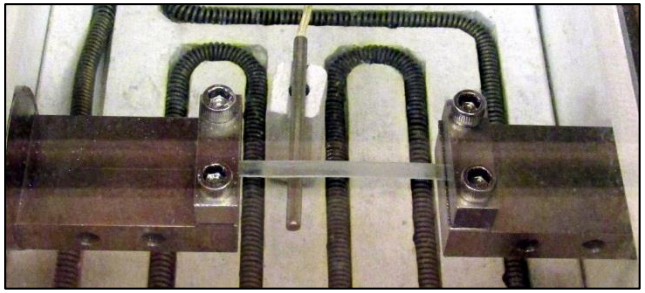


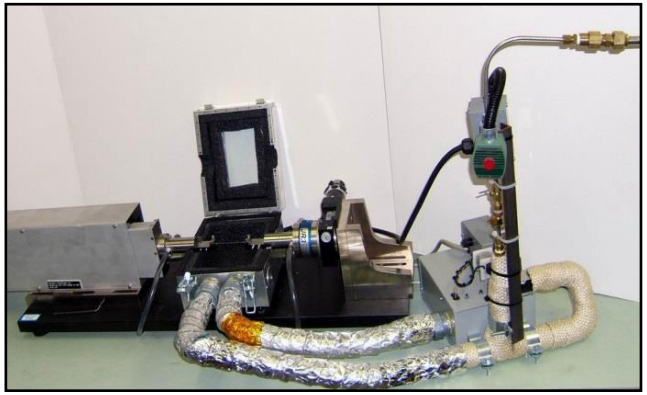
MICROTESTER

Small Scale Mechanical Testing System

Stress-Strain Testing







Temperature Range: -190 to +300 C

POLYCARBONATE

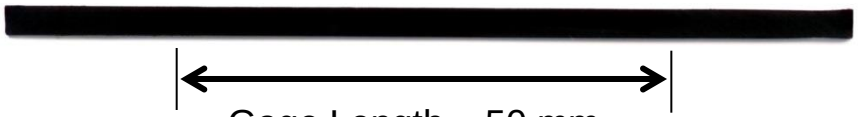
Typical Specimen Deformations (T = 20 C)

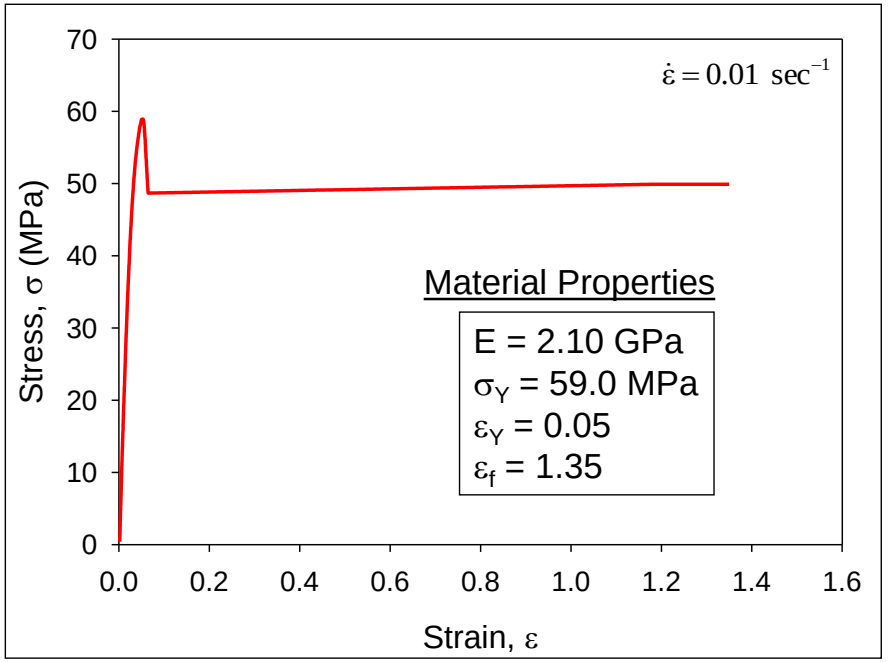
$$\varepsilon = \frac{\Delta L}{L} = 1.35 = 135\% = 1{,}350{,}000\ \mu\varepsilon$$

$$\Delta L = 1.35L$$

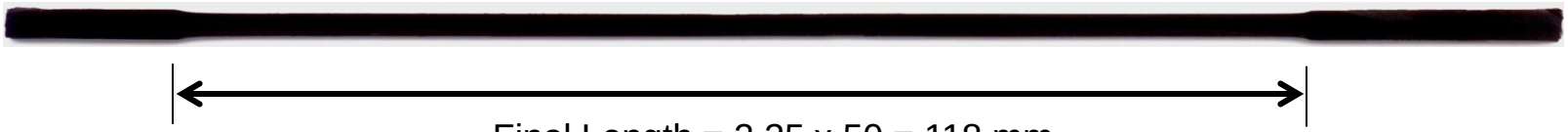
$$L' = L + \Delta L = 2.35L$$

Original Specimen



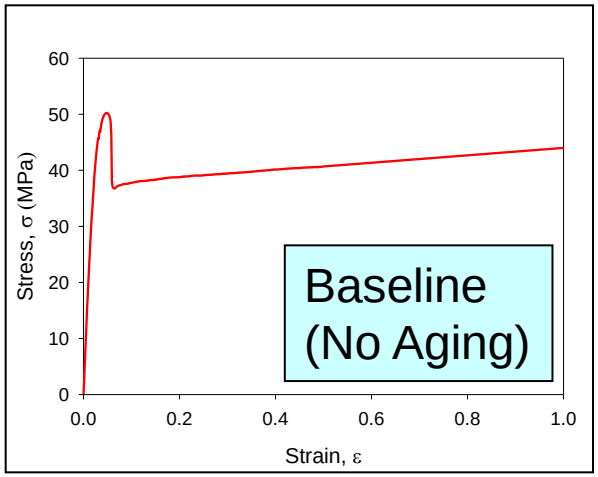


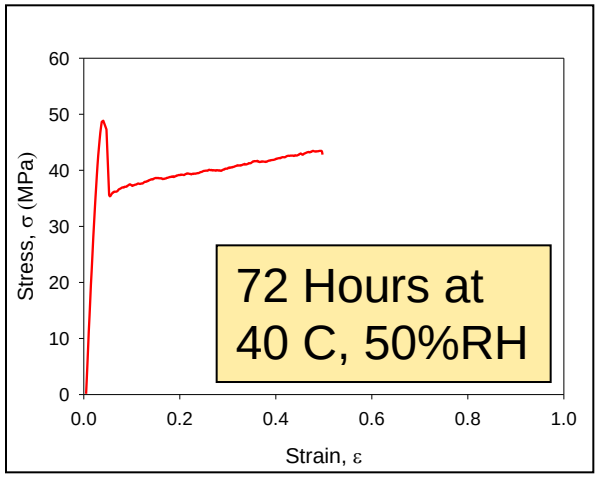
Specimen Just before Failure

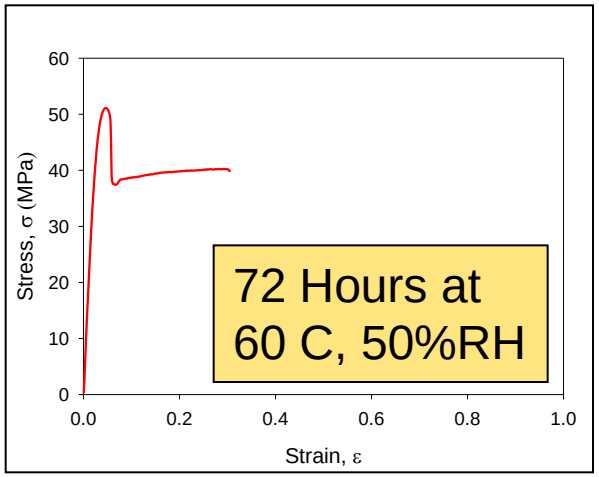


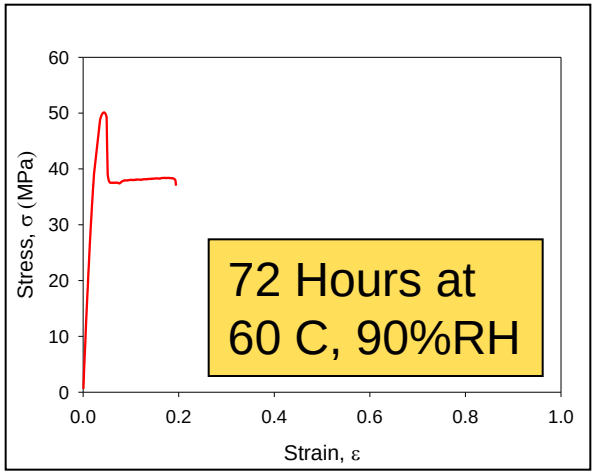
EFFECTS OF AGING

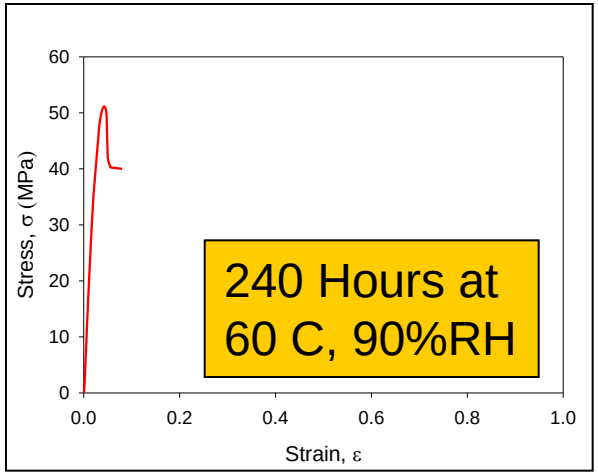
Polycarbonate Stress-Strain Curves (T = 60 C)





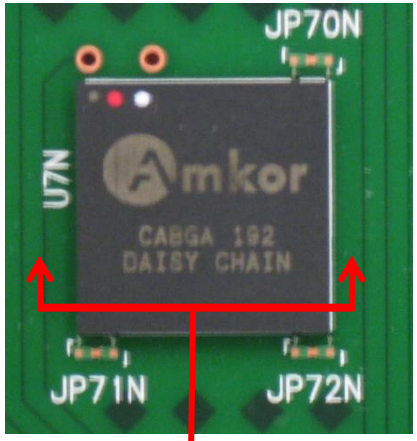


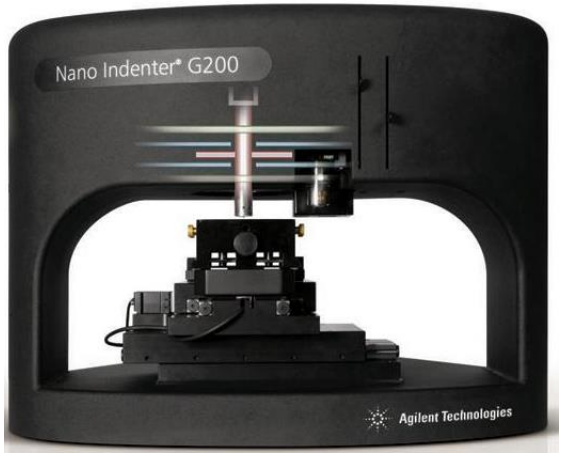


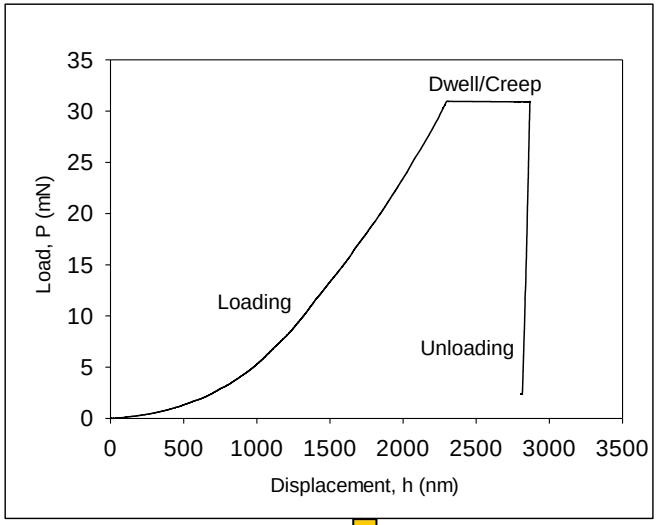


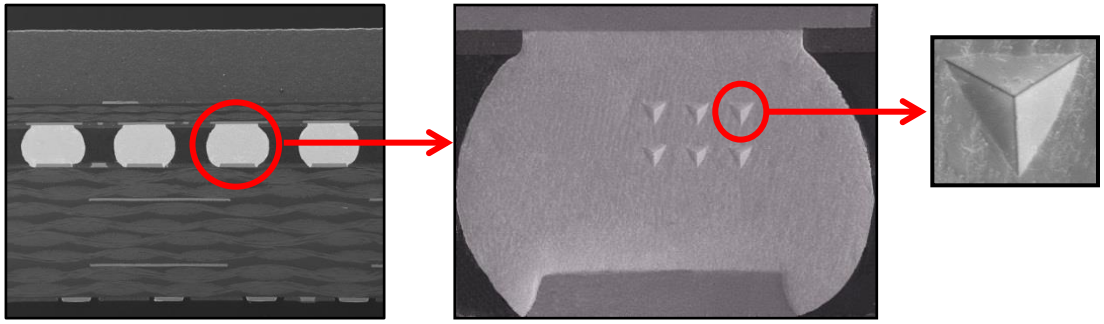
SOLDER APPLICATION

Measurement of Material Properties









$E, H \rightarrow \sigma_{YS}$

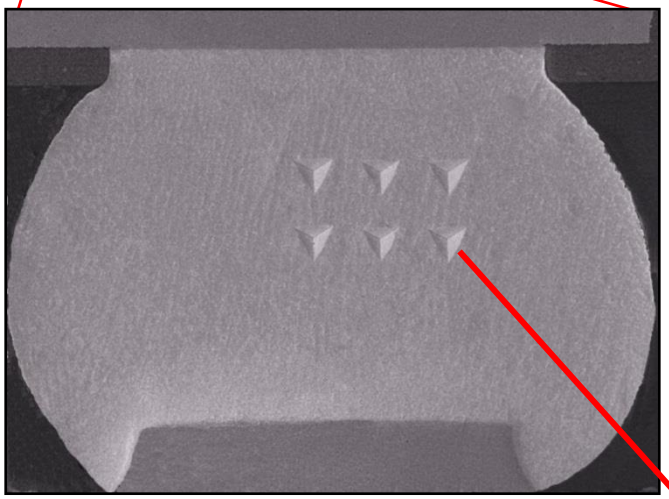
Creep

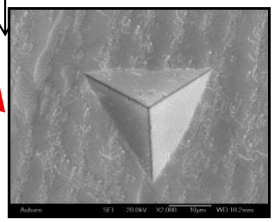
NANOINDENTATION

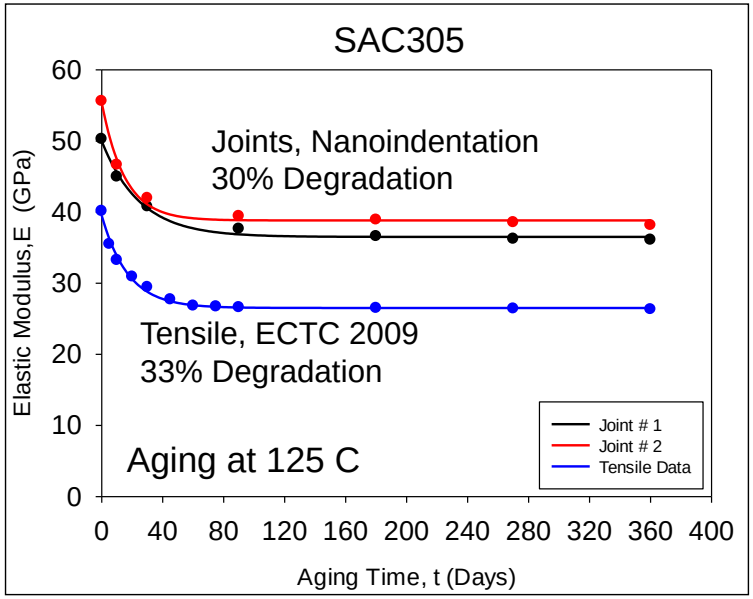
Characterize Aging Effects in Actual Solder Joints

10 x 1 x 0.5 mm

80 x 3 x 0.5 mm







AUBURN UNIVERSITY
SAMUEL GINN COLLEGE OF ENGINEERING

SUMMARY
DEPARTMENT OF MECHANICAL ENGINEERING

ABOUT US

- Two Academic Programs: **Mechanical Engineering** and **Materials Engineering**
- 27 Full Time Tenure Track Faculty
- 1219 Undergraduate Students (Fall 2014)
- 169 Graduate Students (Fall 2014)
- >12,000 Student Credit Hours per Year (2009-2012)
- 139Undergraduate Degrees (2013-14)
- 41 Graduate Degrees (2013-14): 31 MS, 10 PhD
- $8.2M Annual Research Funding (2009-10) [$5-$10M per Year in Each of Past 12 Years]
- Ranked in Top 25 ME Programs by Funding Level
- 254 Publications (2013): 3 Books, 83 Journal Articles, 168 Conference Papers

OUR RESEARCH INTERESTS

- **Materials** (Sensors, Bio/Nano, Detection and Food Safety, Air Quality)
- **Electronic Packaging** (Electronics Reliability in Harsh Environments, MEMS)
- **Vehicle Technology** (Unmanned/Autonomous; Dynamics, Stability, and Controls; Advanced Powertrains: Fuel Cell and Hybrid)
- **Other Areas** (Nanotechnology, Renewable Energy, Fracture Mechanics, Energy Sustainability, Motion Analysis, Fuel Cells, Prognostics/PHM, Acoustics, Nonlinear Optics, Biomechanics, and Many Others)

PROGRAM HIGHLIGHTS

- Rigorous Curricula, Hard Working and Talented Students (Incoming Student Average ACT was 28.3, Fall 2011)
- Nationally Competitive Undergraduate Student Design Teams (Baja SAE, Formula SAE, Solar Car, Lunar Rover, etc.)
- Successful Alumni, Annual Alumni Conference
- Excellence in Scholarship: Research, Graduate Education, Publications: Books, Chapters, Journal and Conference Articles, Extremely Active in Professional Societies and Activities
- National Recognized Outreach Efforts: LITEE, GOP, AETAP
- Excellent Facilities: Wiggins Hall (2012), Advanced Engineering Research Laboratories (2012), Wilmore Hall (2004)

OUR UNIQUE CAPABILITIES

Research Centers

- **MREC** (Materials Research and Education Center)
- **AUDFS** (Auburn University Detection and Food Safety Center, AU Peak of Excellence)
- **ACER** (FAA Center for Air Cabin Environmental Research)
- **CAVE^3** (NSF Center for Advanced Vehicle and Extreme Environment Electronics)