The Measurement, Materials Sustainable Environment Center is a game-changing research facility funded by a $12.3 million National Institute of Standards and Technology grant with additional support from other funding agencies, the University of Kansas and KU Endowment. Opened in fall 2012, this new fixture on the KU School of Engineering complex houses a variety of bioengineering, environmental and infrastructure-related research laboratories and will harness technologies that maximize energy efficiency and minimize adverse environmental impact.

The structure is part of the KU School of Engineering’s Building on Excellence Initiative, a long-term vision that drives growth in facilities, students, faculty, leadership and research.

KU BOLD ASPIRATION THEMES
The KU School of Engineering is proud that research efforts in M2SEC contribute to all four strategic initiative themes of KU’s strategic plan, Bold Aspirations:
- Sustaining The Planet, Powering The World
- Promoting Well-being, Finding Cures
- Building Communities, Expanding Opportunities
- Harnessing Information, Multiplying Knowledge

BUILDING FACTS
SIZE & COSTS
- Gross Square Feet: 46,735
- Net Square Feet: 24,451
- Total Project Cost: $23,827,138
- Building Construction Cost: $19,170,879
- Cost Per Square Foot: $509
- NIST grant provides partial funding

BUILDING SYSTEM COMPONENTS & PERFORMANCE
- Exceeds ASHRAE 90.1 baseline efficiency by a minimum of 30% (LEED Silver equivalent).
- First application of active chilled beams on KU campus.
- Building exterior envelope uses a high performance, closed cell, pressure equalized, polyurethane foam spray application.
- Lab temperature and air flow control system uses Venturi-style valves.
- Variable air volume supply and exhaust system.
- Utilization of low-velocity coils and filters optimizes the value of the system using lower air pressure, reducing overall fan horsepower.
Labotories and spaces in M2SEC reflect a number of research themes and ideals pursued by the KU School of Engineering.

GLOBAL CHANGE
Includes remote sensing used to measure changes in polar ice sheets, UAVs, large data set analysis, glacial modeling, diminishing water supplies.

MATERIALS & TECHNOLOGY
Includes regenerative medicine, medical devices, diagnostics, tissue engineering, drug delivery systems, biomaterials, composites.

ENERGY & TRANSPORTATION
Includes activities in bio-fuels, alternative energy, smart grid technology, power generation, transmissions and distribution, solar energy, bio-refining, energy efficient vehicles, aviation, safety and ergonomics, environmental impacts and transportation infrastructure.

SUSTAINABLE BUILDING PRACTICE
Includes biomaterials, adaptive materials such as phase-change materials, building technologies, intelligent systems, durability water catchment systems, HVAC.

SHARED PROGRAM RESOURCES
GROUND FLOOR
G510  Demonstration Lab
G520  KU Transportation Center
G530  Sustainable Building Conference Room and Sustainable Building Access Corridor
G533  Acoustic Reverberation Suite
G535  Conference Room
G543  Reverberation Lab
G544  Collaboration Spaces
G546  Collaboration Spaces
G547  Anechoic Chamber Workroom (G547A)
Anechoic Chamber
G548  Lutz Fracture and Fatigue (with Strong Room)
G549  Flammable Storage Room
G554  Biofuels Production
G556  Biofuels Research
G557  Engine Test Cell
G558  Biofuels ASTM

FIRST FLOOR
1508  Collaboration Space
1512  Warm Room
1514  Cold Room
1520  Materials Characterization
1530  Sustainable Building Conference Room and Work Room
1533  Sustainable Building Lab and Panel Access Corridor
1537  Multi-use Innovation Lab
1544  Composite Materials
1547  Server Room
1549  Surface Characterization
1550  Biomaterials Laboratory
1553  Mechanical Test Cell
1555  Engine Support Laboratory
G547A  Upper Anechoic Chamber

ROOFTOP FEATURES
Mechanical
Biofuels Greenhouse
Research Roof with Planting Areas
Test Cell Exhaust
Vertical Wind Generator
ACOUSTIC REVERBERATION
SUITE & ANECHOIC CHAMBER

ROOM G533

ACOUSTIC REVERBERATION SUITE

This facility includes two adjacent, acoustically reverberant (“echoing”) rooms with a 4-foot by 8-foot aperture (“window”) between them. The suite is designed to measure Transmission Loss (TL) for room or vehicle walls and absorption coefficients of sound-absorbing materials used in walls or interior furnishings. Flat or slightly curved panels are inserted into the aperture to measure the TL when sound—generated and measured in the south room—is transmitted to the north room. The difference in the measured Sound Pressure Level (SPL) is resolved as the TL on which the panel Noise Isolation Class (NIC) rating is based. Alternatively, the acoustic absorption of objects placed in one of the rooms may be measured by comparing the room reverberation time with and without the test objects. This facility is currently primarily used to devise and evaluate alternative test methods associated with noise reduction and for testing the noise reduction qualities of panels fabricated with new materials and/or new noise reduction schemes. The types of panels to be evaluated include aircraft fuselage side-walls and new building walls. Coefficients of absorption will be measured for various architectural materials including fabric used for variable reverberation control in auditoriums and similar spaces.

MAJOR EQUIPMENT

The chamber, and associated test and measurement equipment, was developed to cover a frequency range from 30 MHz to 18 GHz and is capable of detecting extremely weak emissions in the range between -130 and -150 dBm. There are also options to enable antenna-pattern measurements, using both far-field and spherical near-field scanning techniques over the frequency range of interest.

Over the past few years, the chamber has been extremely valuable in optimizing CReSIS remote sensing systems prior to deployment to both Greenland and Antarctica. The chamber has been used to identify noise sources that can reduce radar sensitivity, measure radiation patterns of large arrays that have been installed on numerous aircraft, and identify interference between radar sensors and avionics on KU’s unmanned aerial systems (UAS).

ANECHOIC CHAMBER

The University of Kansas Center for Remote Sensing of Ice Sheets (CReSIS) has developed an anechoic chamber to test and optimize sensors being developed to support polar research. The chamber also serves as a teaching laboratory for graduate and undergraduate courses relating to antennas, electromagnetic interference (EMI) and electromagnetic compatibility (EMC), offered by the Department of Electrical Engineering and Computer Science. The chamber expands theoretical EMI/EMC subject matter in more practical applications to provide students with a hands-on learning experience.

ROOM G547

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The Biomaterials Laboratory is dedicated to developing biomaterials that possess biomimetic structures with self-healing capabilities and fatigue resistance. This includes a major emphasis on tissue engineering for things like cartilage regeneration in the knee or jaw joint, and the development of novel drug delivery systems to treat a variety of degenerative diseases in tissues and organs.

KU Researchers also are working on discovery of technologies that will reduce cost, improve productivity and assure the efficient delivery of high-quality products. The lab includes many state-of-the-art safety features and brings together faculty and students in similar research areas that were previously in separate buildings to enhance their efficiency and synergy.

This lab plays a critical role in the transition of research to the health-care industry, with participation of scientists, engineers, medical professionals from the KU Medical Center, and industrial partners and is expected to strengthen KU’s position as a regional leader in bioengineering and bioscience research.

“This research has very clear health benefits for many individuals, and a lot of these technologies are reducing costs as well as improving quality of life,” said Stevin Gehrke, director of graduate studies for the bioengineering graduate program and professor of chemical and petroleum engineering.

MAJOR EQUIPMENT
The Biomaterials Laboratory offers 2000 ft² wet lab space fully equipped for biomaterials synthesis and characterization. Within the main lab are two tissue culture labs (200 ft² each, both with two biosafety cabinets, sink and resin countertops and cabinets) and an autoclave room (100 ft²). The main lab includes four 6-foot fume hoods, snorkel hood, four sinks, 160 linear feet of resin countertop space, wall and bench cabinets, 10 linear feet of desk space, and full utilities, including plumbed-in RO water and a Millipore ‘Milli-Q’ ultrapure water system.

The Biomaterials Laboratory is set up primarily for biomaterials sample preparation (including insect rearing) and chemical characterization. It includes:

- Cary 300 UV/Vis spectrophotometer (190-900 nm ±0.02 nm; 0.0-5.0 Abs ± 0.0016 Abs).
- Integrated HPLC-multi-angle laser light scattering system (Shimadzu Prominance) HPLC including: CBM-20A control module, DGU-20A degasser, LC20AB binary gradient analytical/semipreparative pump, CTO-20AC column oven, SPD-20A UV/Vis detector, RF-20A fluorescence detector, RID-10A analytical/semi-prep RI detector, Wyatt Technologies miniDawn TREOS MALLS (for determination of molecular weights, molecular weight distributions and radii of gyration of synthetic and biological macromolecules).
- New Brunswick Scientific Bioflo110 3-L Fermentor/Bioreactor system, rotary evaporator system (Heidolph Precision).
- Eppendorf Centrifuge 5810R (tabletop refrigerated centrifuge) with rotational speed control 10-14,000 rpm; generates up to 18,500g.
- New Brunswick Innova 40R programmable incubating shaker (10° C – 80° C ±0.1° C; 25-500 rpm) and New Brunswick Scientific Innova 2000 Platform Shaker with programmable speed control over the range of 25-500 rpm.
- Labconco HEPA filtered Vertical Clean Bench with UV lamp.

ADDITIONAL EQUIPMENT IN DR. DETAMORE’S LABORATORIES
CELL CULTURE

- Six 6-ft. Class II biosafety cabinets for cell culture.
- 18 CO2 incubators for culture of tissue-engineered constructs.
- Two refrigerated centrifuges.
- Full water purification systems from Millipore with RO/DI (type III) and MilliQ(type I) water.
- Two Cellometer Auto T4 Plus (Nexcelom) for cell counting.
- Freezer Mill (SPEx SamplePrep) for grinding cartilage and other tissues.
SPECIALTY/CUSTOM
- Microsphere fabrication apparatus and a gradient-scaffold fabrication apparatus that together include a Quizix pump (Vindum Engineering), a sonicator, and four syringe pumps (Harvard Apparatus X2).
- Custom-built electrospinning apparatus with aluminum rotating collection mandrel, with two syringe pumps (Harvard Apparatus X2) for fabricating gradients in electrospun materials.
- 4D-Nucleofector (Lonza) for gene delivery.
- Laryngoscope (Karl Storz parsons toddler laryngoscope), with TeleCam and TelePack X monitor, for imaging engineered tracheas in live animals.
- Tissue decellularization equipment.

POLYMER/HYDROGEL SYNTHESIS AND ANALYSIS
- 3D Printer (RepRapPro).
- Beckman-Coulter Multisizer 4 for sizing particles and counting cells: apertures from 20 -2000 µm.
- Glovebox (MBraun Labmaster), dry and inert atmosphere capability, with two workstations, freezer, touch screen controls; shared with Prof. Steve Gehrke.
- Rotary evaporator system (Heidolph Precision), shared with Prof. Steve Gehrke.
- HPLC multi-angle light scattering system (Shimadzu Prominence), shared with Prof. Steve Gehrke.
  - CBM-20A control module, DGU-20A degasser, LC20AB binary gradient analytical/semipreparative pump, CTO-20AC column oven, SPD-20A UV/Vis detector, RF-20A fluorescence detector, RID-10A analytical/semi-prep RI detector.
  - Wyatt Technologies miniDawn TREOS MALLS (for determination of molecular weights, molecular weight distributions and radii of gyration of synthetic and biological macromolecules).
  - Spectroline Spectrolinker UVB (Spectroline) light for crosslinking.

IMAGING
- Zeiss Axio Observer A1 inverted microscope.
- Differential Interference Contrast (DIC) at 10X, 20X, 40X, 63X, 100X.
- PlasDIC contrast (unique to Zeiss for DIC-like images through plastic) at 10X, 40X, 63X.
- Polarizer, reflector module (for imaging biomaterials), fluorescence, and phase contrast.
- 40” 1080p HD television (Samsung, 120 Hz).
- Zeiss Axio Imager A2 upright microscope with its own 40’’ 1080p HD television (Samsung, 120 Hz).
  - Nikon TS100F Inverted microscope (polarizer, fluorescence).

GENE EXPRESSION
- RNaseq spin column (Qiagen).
- Thermal cycler (Bio-RAD iCycler).
- TapeStation (Agilent TapeStation 2200) for protein, RNA and DNA analysis.
- Real time RT-PCR machine (Eppendorf MCEP RealPlex 4S).
- NanoDrop™ 2000° C (Thermo Scientific™).

HISTOLOGY
- Cryotome (Microm HM550 OMP).
- Precision diamond saw (Buehler Isomet 1000).
- Bone vise (Pathology Innovations).
- Paraffin dispenser (Leica EG 1120) for warming paraffin.
- Cold plate (Leica EG1130) for cooling paraffin blocks.
- Autostainer (Biogenex i6000).

MECHANICAL TESTING
- Instron 5848 materials testing machine with 10 N and 50 N load cells.
- Custom-made bath-grip (tension) and bath-platen (compression) assemblies.

BIOCHEMICAL TESTING
- Absorbance and fluorescence plate readers (Thermo Electron).
- BioTek Synergy 2 Multi-Mode Microplate Reader with luminescence capability.
- Three tabletop microcentrifuges.

BIOLOGICAL STORAGE
- 6L lyophilizer (Labconco).
- Liquid nitrogen storage cylinders (Thermo Electron).
- Multiple freezers (-80° C/-20° C) and refrigerators.

STERILIZATION
- Two full-size steam autoclaves (Primus Sterilizer PS5500 20x20”).
- Ethylene oxide chamber (Anderson Anprolene AN74i Sterilizer).
This lab is devoted to the measurement of the mechanical and physical properties of materials.

The properties being measured include, but are not limited to, modulus (stiffness), strain (elongation), fracture properties (resistance to breaking), thermal and electrical conductivity and relative permittivity.

Installed equipment can measure materials ranging from the soft, hydrated synthetic and biological composite materials being developed by Professors Michael Detamore and Stevin Gehrke in Biomaterials Laboratory for tissue regeneration to dry, high performance aerospace composite materials used by Associate Professor Rick Hale in Composite Materials Laboratory. Although the materials and applications are very different, the material properties are measured using concepts with very similar instruments, though ones capable of applying very different magnitudes of forces.

Bringing together researchers with similar material characterization interests from very different fields is expected to generate new ideas in materials design and development.

MAJOR EQUIPMENT

The Materials Characterization Laboratory is set up primarily for polymer synthesis and mechanical testing of materials. Mechanical test equipment includes a TA Instruments RSA III Dynamic Mechanical Analyzer with a mechanical chiller with tools for compression, tension and three-point bending. It can perform a broad range of mechanical tests, including compression and tension in air and in the temperature-controlled solvent chamber, and in static and dynamic modes.

The RSA III DMA consists of three components; the test station itself, an environmental control unit and a control computer. The instrument operates over a frequency range of 6.28 x 10^-6 to 502 rad/s (1 x 10^-6 to 80 Hz) with a strain resolution of ± 0.05 µm and a maximum force 35 N (3500 g). The environmental control section of the RSA III is capable of controlling the temperature of the samples being tested from -80° C to 500° C. Samples can be tested in air or in a solvent chamber in a variety of testing modes, such as frequency and temperature sweeps.

Also included in this room is an AR-2000 Rheometer (TA Instruments), a temperature-controlled rheometer for studying gelation:

- torque range: 0.0001-200 mN.m.
- angular velocity: up to 300 rad/s.
- resolution: 0.04 micro rad.
- normal force transducer: 0.01-50 N.
- Peltier Plate Cooling temperature range: -5° C to 100° C.
- various plate geometries, including solvent trap.

For synthesis, the following items are available:

- MBraun Labmaster glovebox (dry and inert atmospheres) with two workstations, freezer, touch screen controls.
- Two Spectrolinker XL 1000 UV crosslinking chambers (programmable).
- Plas Labs Anaerobic chamber for polymer synthesis in oxygen and water-free environments.
- Shimadzu AEU-210 Analytical Balance, Olympus SZH stereomicroscope with Lasico digital filar eyepiece and video/photo accessories.
This lab is devoted to the measurement of the mechanical and physical properties of materials.
Nanomedicine, an offshoot of nanotechnology, seeks to develop highly specific medical intervention at the molecular scale by developing smart nanomaterials and nanomachines that can autonomously detect, cure, or replace damaged and diseased cells and tissues.

A major challenge in nanomedicine is to develop thorough understanding of the physical and chemical properties of the self-assembled biological structure and design. Additionally, smarter strategies are required for designing nanomaterials that can work synergistically within the human body to provide more efficient medical therapies.

The broad research goals of this laboratory are to address some of the challenges in the field of nanomedicine by developing novel biophysical and biochemical tools to probe the physical rules governing the self-assembly and functioning of biological matter, i.e., Nature’s intricate biological structures, while exploring novel designs for nanocarriers of drugs.

Currently, the major research goals are to employ advances in nanotechnology to understand lipid-protein interactions in healthy and diseased breathing, understanding the early stages of progression of neurodegenerative diseases, while also developing novel molecular compositions and drug-delivery techniques and immunotherapies with increased efficacy by understanding their interactions with cellular architecture.

The Surface Characterization Laboratory contains some space for wet chemistry including a fume
hood, a sink, countertop space, wall shelves and primarily surface characterization equipment: two fluorescence microscopes on vibration isolation tables, several Langmuir troughs with Whilhelmy plates, a dedicated microrheology/microfluidic set-up and full utilities (including compressed air, in-house DI water, an ultrapure Milli-Q water system, provision for nitrogen gas hookups, and vacuum hookups). This laboratory is across the hall from shared space in the Biomaterials Laboratory, which provides space for cell culture, sample preparation and additional space for microscopy.

Wet lab space is available in the Material Characterization Laboratory, also on the same floor. This lab contains analytical scales, water baths, pH meters, and other materials.

**MAJOR EQUIPMENT**

- Langmuir Barrier Trough (small, modified for microscopy) with temperature control from Biolin Scientific for Langmuir monolayer measurements.
- Langmuir Ribbon Trough modified for microscopy) with temperature control from Biolin Scientific for Lung Surfactant Studies
- Additional Surface Tension/Surface Pressure measurement equipment.
- Custom designed Langmuir trough with magnet holders adapted for microrheology studies.
- Combined Fluorescence/Polarization/Phase Contrast Microscope (DM 2500) from LEICA.
- LUCAS EM Camera from Andor capable for recording 120 frames/second.
- Custom-assembled Nikon LVFM fluorescence microscope with motor controls.
- LUCA camera to be used with a custom designed microrheology set-up.
- Home-built microrheometer set-up with custom designed optics from ThorLabs.
- Home-built amplifiers.
- Milli-Q water system for ultrapure water.
- Microscale balance.
- Isotemp water bath.
- Sonicator.
- Vibration isolation tables.
- Electromagnets.
- Wave function generators.
- Power supplies.

**COMPUTERS**

Several upgraded Dell Optiplex 620 and 960 workstations for data acquisition, instrument control, image processing and analysis, word processing and mathematical simulations and analysis are available.

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Developing smart nanomaterials and nanomachines that can autonomously detect, cure, or replace damaged and diseased cells and tissues.
The Composite Materials Laboratory addresses applied and developmental research in environmental remote sensing, energy and transportation.

This laboratory is for researchers to design and construct aircraft, sensors and systems to enable airborne environmental remote sensing, with the primary funded research addressing ice-penetrating radar that can assist Center for Remote Sensing of Ice Sheets (CReSIS) researchers in the quest to capture data and create accurate 3-D maps of ice sheets all the way to the bedrock. Sensor suites have also been developed for fine scale measurements of terrestrial ecosystem structure and biomass.

The lab features a 2.1m x 2m x 6.1m composites oven that can be used to cure composite materials ranging from small coupons to entire airframe structures or vehicle components. Past projects include small and large unmanned aircraft, radar arrays and fairings, wind turbine blades, telescopes and fuel containment devices. The lab also includes refrigerated storage space for pre-impregnated materials that have yet to be cured.

“We had grown out of our previous space in Learned Hall, particularly in light of the multiple federally funded research awards on which we are now working in parallel. This lab provides a professional space that will allow us to repeatedly deliver higher quality on these increasingly larger components,” said Rick Hale, professor of aerospace engineering.

The new lab will also provide space for Prof. Rick Hale’s team to design larger antenna arrays with higher resolution that will enable CReSIS researchers to gather images from deeper in the polar ice sheets, as well as smaller arrays more suitable for distributed unmanned aircraft.
MAJOR EQUIPMENT

The Composite Materials Laboratory addresses applied and developmental research in environmental remote sensing, energy and transportation.

The composite lay-up facility is a 59 m² “clean” room with a 6.7 m² lay-up table and 24.3 m³ of –30°C material storage.

The composite tooling and processing laboratory encompasses 128.4 m², and contains a radial diamond saw, 17.8 cm diamond blade precision sectioning saw, 22.9 cm abrasive cutter, two hydraulic specimen mounting presses, orbital and vibrating polishers and a microhardness tester. Sample inspection and documentation is aided with a Nikon Epiphot inverted reflected light photomicroscope capable of magnification to 1000X, with Polaroid and 35 mm film or digital video capture.

The composite curing facility encompasses 66.3 m² and includes an autoclave for curing thermoset and thermoplastic composite materials, 107 kN and 667 kN electrically heated water cooled platen presses and electronically controlled ovens.

The autoclave is rated to 2.4 MPa and 370°C and has a usable space of 30×30×91 cm. The smallest oven is rated to 370°C and has a usable space of 51×51×46 cm and the intermediate oven is rated to 370°C and has a usable space of 1.5 m x 1 m x .8 m.

The composite materials laboratory also houses an electronically controlled walk-in curing oven capable of 260°C, with a usable space of 2.1 x 2 x 6.1 m.

Teams of faculty, staff and students in recent years have designed, fabricated and flight-tested unmanned aircraft and manned aircraft sensor suites, predominantly for remote sensing in Greenland and Antarctica.
KU is home to the multidisciplinary Feedstock to Tailpipe Initiative®, which includes researchers from chemical and petroleum, mechanical, aerospace, and civil, environmental and architectural engineering and ecology and evolutionary biology. M2SEC has three areas (Biofuel Research Wing, Multipurpose Laboratory, and the rooftop Greenhouse) which contain the majority of the research labs for this group and facilitate collaborative, integrated research.

The Biofuel Research Suite includes a series of adjoining labs focused on producing, testing and certifying alternative fuels and a 350-horsepower alternating current dynamometer capable of examining a vehicle’s drive cycle providing critical data on how experimental fuels influence engine performance and emissions. The Multipurpose Laboratory and rooftop Greenhouse includes light racks and raceway ponds for growing different strains of algae, a pilot scale centrifuge and high-pressure reactor with the goal of finding economically and environmentally sustainable methods for the large-scale, stable production of green gasoline, green diesel, and alternative jet fuels from algal feedstocks.

The laboratory space is approximately 2700 square feet of wet lab separated into three individual spaces. The first laboratory is home to a 40-gallon batch reactor for large scale production of fuel, a small distillation unit for methanol recovery from glycerin, and a soap production facility. Currently, the reactor is used to produce over 100 gallons of biodiesel each week from vegetable oil. A second laboratory is designed for smaller scale research of fuel production. Specific work in this laboratory focuses on the thermochemical conversion of algae to biocrude and biochar. The third laboratory houses the equipment necessary to conduct property testing and characterization of fuels and catalysts. This laboratory routinely conducts ASTM testing of gasoline, diesel, biodiesel, and fuel blends as well as elemental characterization of the biocrude and biochar.

**MAJOR EQUIPMENT**

The Biofuels Research Suite have the capability of producing biocrude and biofuel ranging from 15 mL to 40 gallons.

- Multiple stainless steel Swagelok reactors (15 mL – 60 mL) are available for use with a temperature controlled Techne fluidized sand bath for conducting rapid heat-up and cool down, high pressure batch reactions in smaller reactor vessels.
- Two Parr liquid phase, high-pressure reactor systems (450 mL; 100° C; 3000 psi rating
and 4.8 L; 500°C; 4400 psi rating). Both systems are equipped with temperature and pressure control, sampling ports, and automatic stirring capability.

- A 5-gallon jacketed glass, stirred reactor with integrated temperature control from a recirculating bath and condenser.
- A 40-gallon batch reactor system includes all of the equipment to preheat, dry, and separate the products of the transesterification reaction.
- Buchi Rotavap R-220 EX with a 50 L bulb (30 L batch size) and electrically heated bath for product separation and recovery.
- Two steady state flow reactor systems equipped with temperature controllers, gas purification units, mass flow controllers, and ceramic ovens. The reactors are connected to gas chromatographs equipped with a TCD, methanizer, and FID and a TCD and FID, respectively. One of the reactors is equipped with a Chemiluminescence detector.

The Biofuels Research Suite also has the equipment and expertise to conduct ASTM testing on gasoline, diesel, and biofuels and property characterization of biocrude and catalysts including:

- Agilent gas chromatographs capable of high temperature analysis for quantifying biofuels composition, free and total glycerin, headspace analysis, and simulated distillation.
- Custom configured Agilent gas chromatograph with 2 gas sampling values, 5 columns, and 3 TCD detectors capable of analyzing CO, CO₂, light hydrocarbons, O₂, N₂, NOx, and ammonia. This system was designed for the analysis of potential gases produced by the thermochemical conversion of biomass.
- Inductively coupled plasma optical emission spectroscopy for elemental analysis of both aqueous and organic samples and a PAC Antek MultiTek total sulfur analyzer, a total nitrogen analyzer, and a halides analyzer capable of analyzing liquid and solid samples.
- Cold weather properties including cloud point, pour point, and cold filter plugging point.
- TA Instruments Q600 simultaneous differential scanning calorimeter and thermogravimetric analyzer capable of reaching 1500°C.
- Varian HATR FTIR with GladiATR accessory and a Harrick in-situ high temperature DRIFTS cell capable of reaching 800°C in a controlled atmosphere in batch or flow mode.
- Isotope exchange and transient study unit equipped with a quadrupole mass spectrometer. The flow system is equipped with a temperature controller and mass flow controllers. The systems are used for isotopic labeling studies and temperature programmed studies (TPR, TPD, TPO) for characterization of the materials prepared.
- Agilent HPLC system with UV detector.
- Heated centrifuge for water and sediment testing, automated flash point, kinetic viscometer, Metrohm titration system for acid and iodine number, vapor pressure, atmospheric and vacuum distillation, Karl Fisher titrator for water content, copper strip corrosion, carbon residue, Rancimat Oxidation Stability analyzer.
- Parr bomb calorimeter capable of testing small and large samples.
ENGINE TEST CELL

ROOM G557

FACULTY

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As part of the multi-disciplinary university wide Feedstock to Tailpipe® research program, faculty members investigate the production of alternative fuels from a multitude of feedstocks (both petroleum and biomass-based) examining water and nutrient usage. Through subsequent combustion of these fuels in single-cylinder and production engines, models and regression analysis relate performance parameters to fuel properties. Coupling this information with data collection on hazardous and greenhouse gases emanating from the engine allows for a complete system understanding. Including land availability and the impact of the emissions on the climate helps extrapolate the results into a global understanding of alternative fuels.

The engine combustion inquiry involves three synergistic laboratories. A student-designed single-cylinder compression ignition (CI) engine test cell in 1109B Learned Hall allows researchers to design unique liquid and gaseous fuels while diagnosing how small changes in fuel properties (e.g., viscosity) influences fuel economy and emissions (e.g., nitrogen oxides).

The lessons learned are scaled up into a state-of-the-art multi-cylinder CI engine testing facility (381 sq. ft control room and 440 sq. ft test cell), specifically designed to handle the air and emissions requirements of internal combustion engines. Use of a production engine in M2SEC ensures that the fuels are suited for both customer and regulatory agencies.

Furthermore, a one of a kind catalytic reformer and spark ignition setup on West Campus provides an additional avenue of analysis through investigation of fuel production byproducts (e.g., glycerin and biogas). Finally, after including supplementary efforts in waste heat recovery and hybrid electric vehicles, the entire range of combustion analysis is available within a single university setting.

### MAJOR EQUIPMENT

**Single-cylinder (1109B Learned Hall)**
- Yanmar L100V Compression Ignition (compression ratio = 21.2), 5 kW @ 3600 rpm, Bosch CP3.2 high pressure fuel pump; MS15.1 Diesel Electronic Control Unit, Cooled EGR system with two K-33 ICB CO2 sensors, Aerocharger 53-series turbocharger, FUTEK model TRS605 torque-sensor.
- DyneSystems 12 hp/21.1 ft-lbs maximum regenerative air-cooled Alternating Current dynamometer (0-7500 rpm); steady-state and transient testing capabilities; Inter-Loc V multi-loop controller.

**Multi-cylinder engine (G557A M2SEC)**
- 6.6L GM Duramax Compression Ignition (compression ratio = 16.8), 365 hp @ 3100 rpm, 660 lb-ft @ 1800 rpm, OHV four-valves per cylinder, 26000 psi high-pressure common rail injection with Bosch CP3 injection pump, variable geometry turbocharger.
- DyneSystems 351 hp/921 ft-lbs maximum regenerative air-cooled Alternating Current dynamometer (0-7500 rpm); steady-state and transient testing capabilities; Inter-Loc V multi-loop controller.

**Fuel Reformer & Multi-cylinder engine (Hill Engineering Research and Development Center)**
- Custom Ni/Al2O3 reformer, propane/CNG-gas line, compressed air system, glycerin-injection nozzle, 9000VDC spark plug igniter.
- Chevy 350 V8 small block (compression ratio = 8.2), Mecc Alte ECO32-2L/4 generator, Merriam Laminar Flow Element, Kistler-based in-cylinder piezoelectric pressure transducer system.
The Multi-Use Innovation Lab serves as a space for projects that may ultimately reach the pilot stage and as an additional facility to carry out alternative fuel panel research that is also the focus of the roof-top greenhouse.

**MULTI-USE INNOVATION LABORATORY**
The laboratory provides bench space to perform chemical biomass characterization and solids analysis protocols, as well as thermochemical conversion of biomass. The laboratory contains two six-foot chemical fume hoods and one floor-mounted, ventilated enclosure of a PARR high-pressure, high-temperature reactor. For algal growth experiments, a light cabinet provides 6 flat-panel batch reactors and 19 cylinder batch reactors that are exposed to a photoperiod and CO₂ gas injection. Laboratory equipment is also available in the lab: shaker incubators, two stationary incubators, ovens, water baths, pH and conductivity probes, a centrifuge, analytical balances and bench space for chemical analyses.

**GREENHOUSE FACILITY**
The greenhouse is equipped with evaporative cooling, a shade system, programmable grow lighting (HS bulbs), and a Wadsworth environmental controller. Two raceway ponds (1100 liters each) are installed (Waterwheel Algae Technology) with continuous YSI multi-probes for data acquisition of pH, temperature, conductivity, salinity, dissolved oxygen, oxidation-reduction potential, and photosynthetically-active radiation. The greenhouse also houses a pilot-centrifuge for algal dewatering from Evodos.

**MAJOR EQUIPMENT**
- Greenhouse with shade system, evaporative cooling, and Wadsworth environmental controller.
- Two 1100-L raceway ponds with YSI multi-probe monitoring for physical and chemical parameters.
- Evodos (Type 2/10) algal centrifuge that is specified to produce biomass with > 20% solids.
- Flat panel photobioreactors (15L) with controlled CO₂ injection.
- 19 cylinder photobioreactors with controlled CO₂ injection.
- LICOR light meter.
- UV-visible light spectrophotometer
- PARR high-pressure, high-temperature reactor inside a floor-mounted, ventilated enclosure.
- Reactor vessels ranging from 30 mL to 450 mL. The smaller vessels are able to operate up to 600° C (with varying ramp rates) and pressures up to 4500 psi, while the larger vessel can operate up to 350° C and 2500 psi.
The Lutz Fracture and Fatigue Laboratory is one of the best facilities in the country to simulate fatigue loads and to perform material characterization. It includes static and servo-hydraulic test equipment. A structural testing room for component and reduced-scale model testing has 360 ft² of reaction floor space with orthogonal reaction walls on two sides of the test floor and a reaction ceiling with a clear height of 12 ft. Loads up to 100 kips can be applied using jack systems and servo-hydraulic actuators attached to tie-down locations on multiple planes. The tie-downs are evenly spaced 2 ft. on center throughout the floor, walls, and ceiling of the testing room.

Cyclic and dynamic testing of full-scale structural components or reduced-scaled models can be performed using an arrangement of servo-hydraulic actuators and hydraulic rams. Actuators are controlled with an MTS Flextest 40 controller capable of controlling up to three actuators separately or in tandem and are used to apply static and fatigue loading to structural components. Servo-hydraulic actuators are powered using an MTS Silentflo hydraulic power unit with a rated flow of 120 gpm. The Lutz Fracture and Fatigue Laboratory also has two servo-hydraulic test frames with capacities up to 110 kips. 35-kip and a 110-kip closed loop servo-hydraulic universal testing systems (MTS and Instron) are housed in a 200 ft² area dedicated to performing small component and material testing.

Multiple National Instruments data acquisition systems can be configured to be used independently or jointly to monitor and record load, strain, and displacement in tests of different scales. An area of the laboratory is also dedicated to preparation and instrumentation of specimens.
In the United States buildings consume about 40% of the energy that is used in the country. Nearly one-half of this energy is used by building comfort systems (i.e., space heating and cooling systems), which in a significant part function based on how much heat, air, and water vapor is transferred through the building’s external walls (i.e., enclosure).

**MAJOR EQUIPMENT**

The M2SEC Building was constructed in such a way that it is an experiment in itself. Its walls constitute a new research concept known as “plug-and-play walls (PPWs).” The PPW enables, among other possibilities, the experimental characterization of the thermal, hygroscopic (i.e., water attraction and retention), and air transfer properties of building materials in several kinds of wall constructions at the same time under the same weather and indoor conditions.

For this, its south and west facing walls are subdivided into 60 interchangeable wall panels, each of which can be assembled in any type of building wall and/or dismantled with relative ease. For example, several types of building walls (i.e., steel frame, wood frame, concrete, brick, composite, etc.) can be tested together at the same time or independently during any season of the year. The PPW concept makes the M2SEC one of only a handful of buildings worldwide with the same capabilities.

In addition to materials characterization, the PPW is being used to test the new generation of building materials, insulation systems, and building wall technologies in general. The focus of the research is to develop energy efficient walls, with reduced rates of heat and mass transfer, for energy conservation and management, as well as reduced building carbon footprint and to utilize renewable and passive technologies within the building enclosure. Current research includes the characterization of building walls outfitted with phase change materials and nano-aerogels. Both of these are technologies that help in reducing heat transfer across building walls.
Additional capabilities found in the Sustainable Building Laboratory include two fully-instrumented conference rooms for control studies of energy consumption as well as wall heat and mass transfer studies. A separate space, facing east, is used for fenestration studies (i.e., windows). This space is equipped with removable glass frames in which fenestration properties, such as solar and infrared transmissivity, absorptivity, and reflectivity can be studied. In addition, windows outfitted with phase change materials, nano-aerogels, and other emerging technologies can be investigated.

The experimental data are used to validate transient heat and mass transfer models, which are developed in-house, as well as to calibrate commercially-available building energy simulation software.

Equipment used in these spaces includes heat flux meters, thermocouples, infrared thermometers, relative humidity transducers, anemometers, a differential scanning calorimeter, hard-wired and wireless data loggers, and computers.
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