MAINE OCEAN & WIND INDUSTRY INITIATIVE

Composite R&D, Testing and Manufacturing Resources

The Maine **Composites** Alliance

- **Plastics Engineering Processing Laboratories**
- **Materials Characterization Laboratory**
- **Renewable Energy Laboratory**

Faculty Expertise - UMass Lowell

University of Massachusetts Lowell

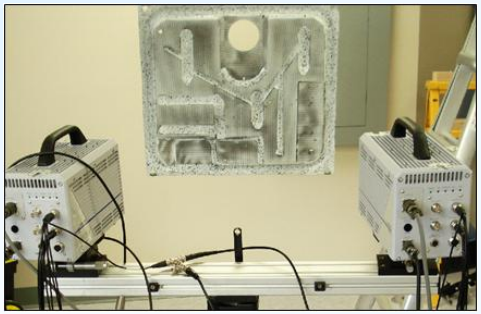
- Christopher Niezrecki (Director) – **Structural dynamics**, **non-destructive inspection**, **structural health monitoring**, acoustics, smart structures and materials, active vibration control, blade testing
- Peter Avitabile – **Structural dynamic modeling** using analytical and experimental methods, experimental **modal analysis** testing, test/analysis correlation and updating of models, **finite element modeling**
- Julie Chen – **Composites** and composites manufacturing, fibers and textile structures, experimental characterization of structural behavior
- James Sherwood – **Finite element modeling**, modeling of composite manufacturing processes, linking of the manufacturing process to the structural performance, high-speed impact
- Christopher Hansen – Composites manufacturing and experimental **characterization of composites**
- David Willis – **Computational aerodynamics**, multi-fidelity unsteady potential flow methods, fluid-structure interaction
- David Turcotte – Firm and industry level educational and skills needs assessment and resource identification, labor market trend analysis, and supply chain opportunity assessment, **workforce development**
- Tzu-Yang Yu – **Distant radar inspection**, synthetic aperture radar imaging, electromagnetic wave-medium interaction, dielectric measurement and modeling of multiphase media, electrodynamic simulation, wavelet analysis
- Eugene Niemi – **Aerodynamics** of wind turbines, blade motion, response to gusts and tower support flow disturbances; wave effects on offshore wind turbine towers
- Emmanuelle Reynaud – Experimental study and analytical modeling of materials structure-properties relations, mechanical, dynamic mechanical / rheological and thermomechanical materials analysis, indentation and nanoindentation testing, **polymer composites and nanocomposites**, inorganic glasses and hard coatings
- Daniel Schmidt – **Materials chemistry**, processing, analysis and structure-processing-properties relations, with specializations in thermosets, nanocomposites and nanoparticles, polymer-derived ceramics, thermal, barrier and fire properties measurements, and sustainable materials.
- Murat Inalpolat – **Condition monitoring** of gear trains and bearings, signal processing, and acoustics
- Robert Giles – **Radar signatures** of field structures/vehicles and sub-millimeter wave inspection
- Samuel Paikowsky – static and dynamic testing and analysis of **deep structural foundations**

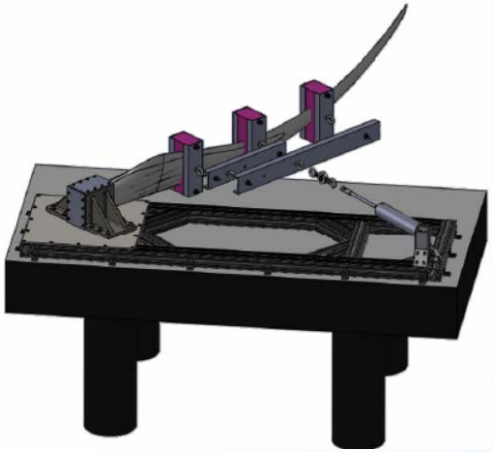
Southern Maine Community College, Composites Engineering Research Laboratory (CERL)

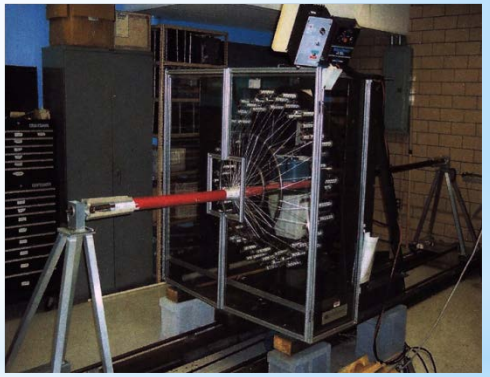
- Andrew Schoenberg – **Composites manufacturing**, workforce development, technical assistance for industry

UML Capabilities and Facilities

- **Structural Dynamics and Acoustic Systems Laboratory**
  - 3D scanning laser vibrometer
  - 3D digital image correlation
  - High speed video capture
  - Wind turbine blade test stand
- **Advanced Composites & Textile Research Laboratory**
  - Composites processing with VARTM, vacuum diaphragm, hot press, braiding
  - Mechanical testing, fiber and textile characterization
  - Computational capabilities include ANSYS, ABAQUS, LS-DYNA, NASTRAN, FEMAP, etc.
- **Thermal Analysis Laboratory**
  - DSC, DMA, TGA, rheometer

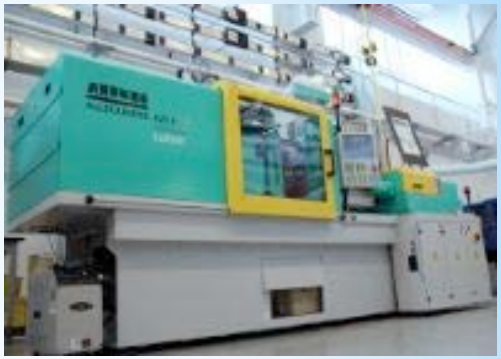


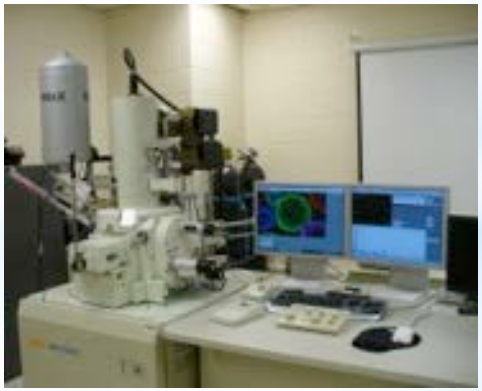




UML Capabilities and Facilities

- **Plastics Engineering Processing Laboratories**
  - Largest academic collection of plastics equipment in U.S.
  - Extrusion, thermoforming, blow molding
  - High-bay facility
  - Center for High-Rate Nanomanufacturing
- **Materials Characterization Laboratory**
  - Optical, electron, atomic, fluorescence microscopy
  - Numerous additional capabilities listed at https://crf.uml.edu/
- **Renewable Energy Laboratory**
  - Hybrid wind/photovoltaic grid
  - Energy storage and smart grid evaluation



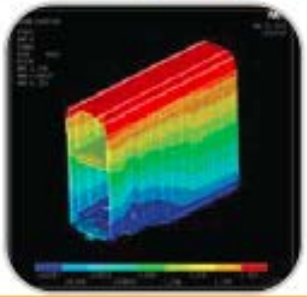


Wind Technology Testing Center

- Massachusetts-NREL Wind Technology Testing Center
- http://www.masscec.com/wttc
- Full suite of certification tests for turbine blades up to 90 meters in length

TPI INNOVATION DEPLOYMENT TEAM

Mission: Create sustainable competitive advantage for TPI through deployment and protection of advanced technology. Reduce cost of energy - improve performance & reliability while reducing blade cost.



FALL RIVER WIND BLADE INNOVATION CENTER

- 69K sq ft facility with water access
- Enable 45M to 62M+ prototype wind blades
- Conduct blade innovation
- Build initial prototype blades
- Build pilot production blades
- Dial in production tooling
- Create production documents
- Technology transfer
- Phase II expansion opportunity

C.E.R.L.
COMPOSITES ENGINEERING RESEARCH LABORATORY

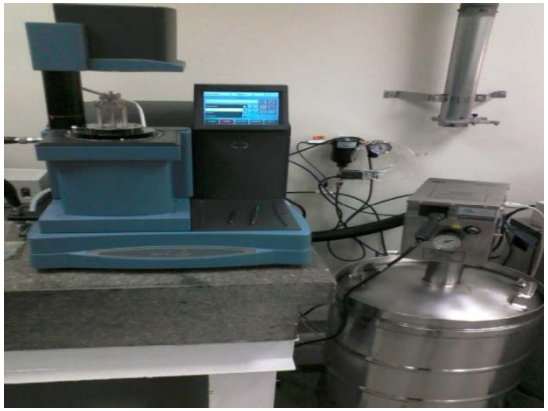
CERL Directive and Scope

- The directive of the laboratory is to partner with Regional Composite Companies to address their engineering and applied research needs to allow them to be more productive and competitive in the global composites marketplace
- The scope of the laboratory can be sub-divided into 3 levels of support:
  - Level 1 – Quality Control Testing: Once test methods are developed, this testing would be for routine or repetitive data collection.
  - Level 2 – Methods Development and Unknown Sample Testing: This testing would require methods development and engineering interpretation of results. The fee structure would relate to the two components of this testing
  - Level 3 – Product Development / Process Optimization: This support would incorporate both significant engineering support as well as, as needed analytical testing support. The fee structure can be hourly / instrument time, or per project

Targeted Sectors

Marine	Construction	Alternative Energy	Avionics / Aerospace	Consumer
• Engineering FRP • Hand layup • Vacuum Infusion • Unsat. polyesters • Gel Coats	• Filament Winding • Pultrusion • Chemical Resistant Products • Infrastructure • Unsat. Vinyl esters	• Windblade manufacture and repair • Hydro-kinetics	Advanced FRP • Carbon fiber TS • Epoxies • Carbon fiber TP • PEEK, PS • Elevated Temperature Molding	• Sheet and bulk molding compounds • Electronics composites • TP thermo-forming • TP composites • Decorative Laminates • Solid Surfacing

Fully Equipped Composite and Polymer Characterization Lab



Composites Science and Manfacturing Facilities

MANUFACTURING, QUALITY CONTROL TESTING, AND INFRASTRUCTURE

Advanced Manufacturing

Quintax 5 axis CNC Router

Vacuum Thermal Forming Machine

Wisconsin Large Volume Oven with
In-Situ Vacuum Forming Capability
4 stage Manifold Station for VIP

Composites Science and Manufacturing Course Outline

Semester 1	Semester 2	Semester 3	Semester 4
COMP100 – Introduction to Composites	COMP150 – Composites Materials COMP105 – Closed Mold Manufacturing	COMP110 – Composite Repair COMP115 – Composite Layup and Design COMP160 – Fundamentals of Quality & Testing MTSC100/AEDD255 – Introduction to Materials Science	COMP200 – Advanced Composite Processes COMP205 – Polymer Technology COMP210 – Lean Manufacturing COMP250 – Composite Internship

Top Down 10,000 foot view with each subsequent course building from the previous course.
Drilling down in perspective and detail to the final industry partnered internship.

1865 THE UNIVERSITY OF MAINE

ADVANCED STRUCTURES & composites center

UMaine's Advanced Structures and Composites Center ISO 17025-accredited testing laboratory in Orono, Maine.

11 INTEGRATED LABORATORIES

- Structural and Wind Blade Testing Labs
- W2 - Wind/Wave Hydro-Aerodynamic Testing Basin
- Materials Characterization Labs
  - Mechanical Testing Lab
  - Environmental Testing Lab
  - Polymer Characterization Lab
  - Microscopy
- Manufacturing Science Labs
  - Composites Advanced Manufacturing Lab
  - Kenway Composite Materials Lab
  - Strand Composites Pilot Line
  - Thermoplastic Composite Extrusion Lab
  - Nanocomposites Processing & Analytical Lab

ADVANCED STRUCTURES & composites center

DESIGN AND SIMULATION CAPABILITIES

- Finite element analysis in ANSYS or ABAQUS
- Nonlinear material modeling including impact and fatigue
- Multiphysics simulation in LS-DYNA
- Creation of application-specific analysis software
- Finite-element software development
- Fluid-structure analysis in WAMIT or ANSYS Aqwa
- Coupled floating wind turbine analysis in FAST

MANUFACTURING CAPABILITIES

- Thermoplastic vacuum consolidation
- Vacuum assisted resin transfer molding
- Wood-plastic extrusion
- Filament winding
- Compression molding
- Property enhancement using nanomaterials
- Low-logistics concrete formwork
- Hybrid concrete/composite structures

IAS™ ACCREDITED

An ISO 17025 accredited testing laboratory.

STRUCTURAL TESTING CAPABILITIES

- Total reaction floor space 845 m^2
- Test structures up to 70 m long
- Reaction wall static capacity > 30,000 kN·m,
- Reaction wall fatigue capacity > 20,000 kN·m
- Large and small scale fatigue testing
- 10 servohydraulic actuators ranging from 100 to 1,300 kN
- Six winch frames with 130 kN static capacity
- Two MTS inertial resonance excitation systems
- Complete fixturing and instrumentation services
- Extensive digial image correlation capabilities

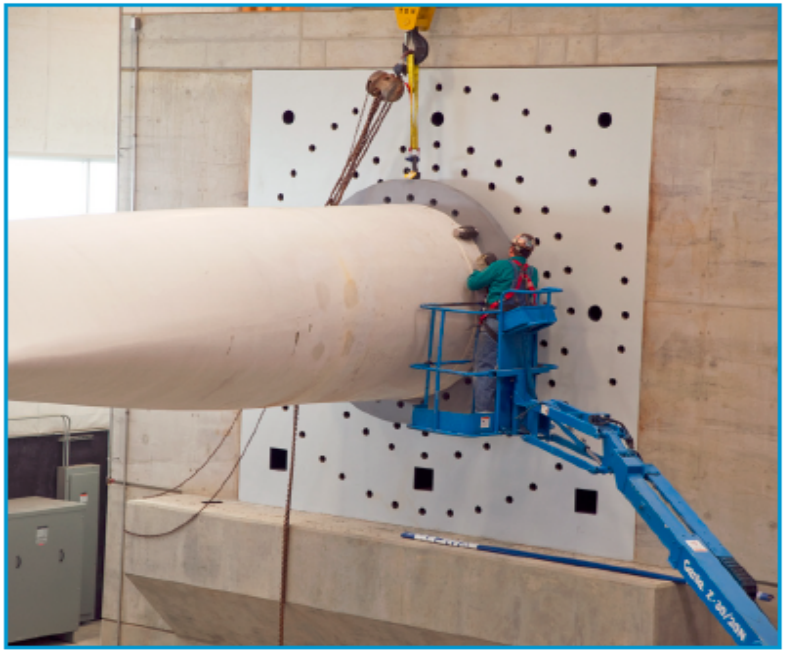
TESTING EQUIPMENT

ADVANCED STRUCTURES & composites center

The UMaine Composites Center is an ISO 17025 accredited testing laboratory with nearly 20 years of testing experience meeting industry standards from coupon-scale to full-scale. Our dedication to industry responsiveness and fast turnaround have led to nearly 300 product development and testing projects over the past five years. Our facility includes fully equipped, integrated laboratories to develop and test durable, lightweight, corrosion-resistant material solutions for a wide variety of industries including, among many, offshore wind energy, civil infrastructure, and electrical utilities.

IEC 61400-23 WIND BLADE TESTING

- Static proof loads to > 30,000 kN·m
- Fatigue loads to > 20,000 kN·m
- Natural frequency and damping measurements
- Blade rotation system with >150 kN·m brake system
- Digital image correlation to characterize surface buckling
- Rolling ultrasonic probe to inspect adhesive joints
- Root stud pull-out testing



Offshore Wind Laboratory reaction wall

STRUCTURAL TESTING EQUIPMENT

845 m^2 available reaction floor space

Servohydraulic static and dynamic tests
- MTS and Instron systems

Structural test frames (vertical reaction)
- 3 x 1300 kN capacity
- 1 x 450 kN capacity
- 1 x 220 kN capacity

Structural test walls
- 1 x 3200 kN·m capacity
- 1 x >30,000 kN·m capacity

Winch frames
- 6 x 130 kN capacity

Servohydraulic actuators
- 2 x 1300 kN (2000 kN in compression)
- 3 x 450 kN
- 3 x 250 kN
- 2 x 100 kN, 1 high-speed (1.2 m/s)

Hydraulic power stations
- 280 kW in Offshore Wind Laboratory
- 170 kW in Structural Testing Laboratory

NONCONTACT DISPLACEMENTS AND STRAINS

- GOM ARAMIS optical 3D deformation analysis
- Displacement resolution 0.1 mm over large surfaces
- Strain distributions around joints
- 4 sets of cameras

ADVANCED STRUCTURES & composites center

MATERIAL COUPON TESTING EQUIPMENT

Servohydraulic tension-compression test frames
- 1 x 500 kN capacity
- 3 x 100 kN capacity
- 1 x 20 kN capacity

Servohydraulic axial / torsional test frames
- 1 x 100 kN / 1100 N·m capacity
- 1 x 25 kN / 100 N·m capacity

Drop weight impact testing machine, 1.5-1250 J

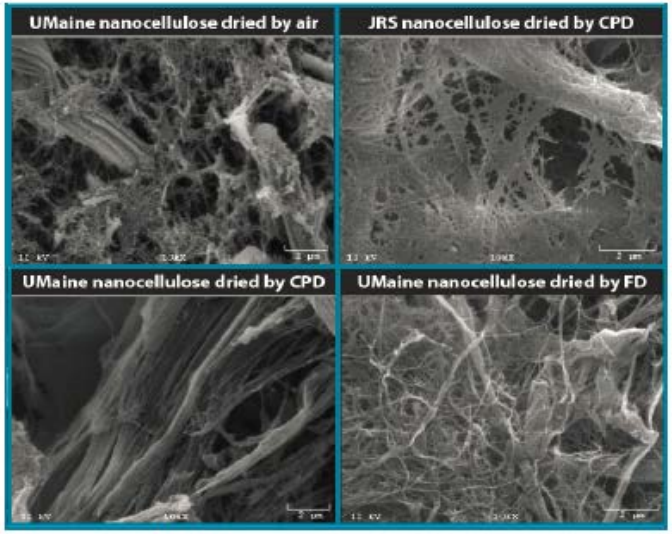
NON-DESTRUCTIVE TESTING

- Phased-array ultrasonic inspection
- Acoustic emission testing
- Embedded fiber optic strain sensing

MICROSCOPY

- Optical microscopy
- Scanning electron microscopy (SEM)
- Environmental SEM
- Transmission electron microscopy
- Atomic force microscopy (AFM)
- Microtomography
- Laser scanning confocal microscopy

Coupon testing in the Mechanical Testing Lab



Nanomaterial development

MATERIAL AND SUBSTRUCTURE TESTING

- Plastic, adhesive, composite, and fabric property testing
- Multiaxial strength and stiffness
- Application-specific fatigue, creep and impact testing
- Multi-scale tests from constituents to structures

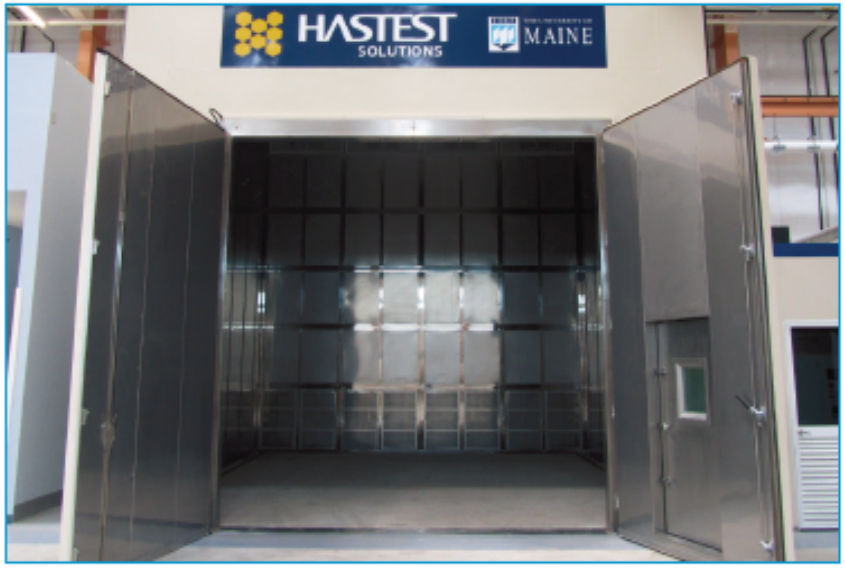
ENVIRONMENTAL TEST CHAMBER

300 m^3 chamber (6.8 m x 6.8 m x 6.1 m high)
Door opening 4.3 m x 4.25 m high
Temperature range -40 to +50°C
- Uniformity ±3.0°C, constancy ±0.2°C

Relative humidity range 20 to 95%
- Uniformity ±5%, constancy ±2.5%

Ramp rate in thermal cycling ±10°C per hour
Capability to conduct fatigue tests within chamber

Panorama of Structural Testing Laboratory



300 m^3 Three-story tall environmental test chamber

Clarkson

UNIVERSITY

defy convention™

Facility Capabilities

Clarkson UNIVERSITY defy convention

- **Structures and Materials Testing Laboratory**
- **Blade Test Facitity**

- Full-scale/scaled wind turbine blade testing up to 15 meters
- New rotor blade designs with cost effective testing capabilities
- Material selection, evaluation of the structural lay-out
- New testing methodologies in support of NREL and SANDIA

Testing Services

Clarkson UNIVERSITY defy convention

A wide portfolio of services for Wind Turbine Blade Testing:

- A range of certification testing services
  - IEC 61400-2
  - IEC 61400-23
  - AWEA 9.1
  - MCS 006
  - RUK 2014 (formerly BWEA 2008)
- Rotor blade design validation
- Manufacturing quality verification
- Validation of repairs and design changes
- Rotor blade – hub integration
- Structural integrity static/dynamic uniaxial/combined loads

Additional wind structures services:

- Testing nacelles and towers
- Testing advanced blade sensing and actuators
- Testing of material/structural coupons (*)
- NDT methods developed for rotor blades (*)
- Testing advanced pitch and stall control algorithms (*)

• Conducted via Center for Advanced Materials Processing

Clarkson University Wind Tunnel

Clarkson UNIVERSITY defy convention

Clarkson University Subsonic Tunnel # 1
80 m/s subsonic tunnel outfitted for aerodynamic testing with a 6 component force balance, several position control systems, particle image velocimetry (PIV), laser doppler velocimetry (LDV) and flow visualization. Suitable for aerodynamic testing, scale and small wind turbine testing.

Clarkson University Subsonic Tunnel # 2
12 m/s subsonic tunnel with high inlet air quality, established through 228 sq. ft. of HEPA filter. Suitable for aerosols testing and environmental / low speed wind testing.

Structures and Materials Testing Laboratory

Clarkson UNIVERSITY defy convention

- Reaction frame can accommodate test specimens in an 14 m long, 8 meter wide, and 5 m tall test volume.
- Reaction frame floor and walls are outfitted with anchorages that are positioned in a 1.2 m uniform grid.
- 5 ton overhead crane.
- Testing equipment includes a range of hydraulic actuators, 60GPM Instron hydraulic power supply, servo controllers, a modular structural steel testing frame, two axial load testing frames, an axial-torsion combined loading frame, state-of-the-art high-speed control and data acquisition systems.
- Folding safety partitions (blast walls) protect technicians from injury during destructive testing and to potect IP from observation during closed-door testing.

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www.mainewindindustry.com

Paul Williamson
Portland Maine
207-242-3521
pw@mainewindindustry.com