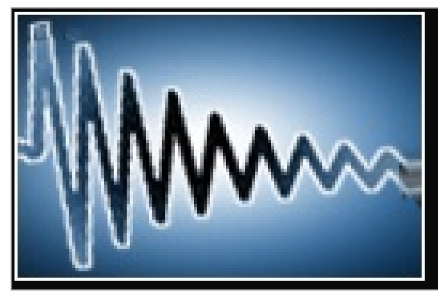
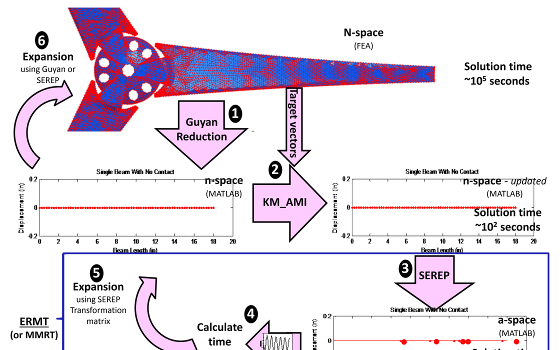


Structural Dynamics and Acoustic Systems Laboratory
University of Massachusetts Lowell

SOME RECENT STUDENT THESIS/RESEARCH/PROJECT WORK IN THE SDASL (2013-2016)

MASTER'S RESEARCH – JULIE HARVIE

Computationally Efficient Reduced Order Models for Full Field Non-Linear Dynamic Strain Predictions

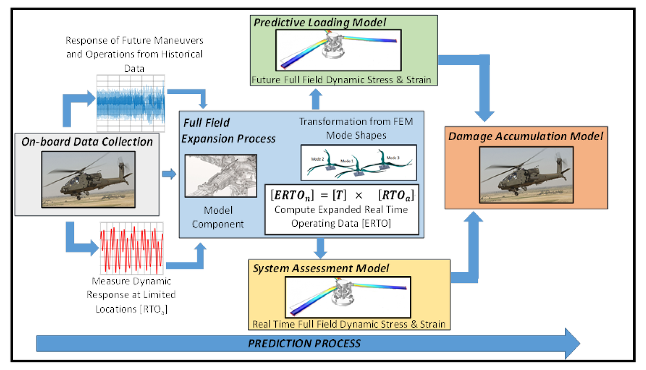


ABSTRACT

Alternative methods are available to compute the dynamic response of both linear and nonlinear systems. The proposed approach utilizes highly reduced order models to determine the response of a system with local nonlinear connection elements at a limited set of nodes; the approach involves approximating the system as piecewise linear rather than employing a nonlinear solution scheme. Once the time response is calculated at the reduced set of nodes, a single transformation matrix is used to expand the results to full space regardless of the configurations encountered.

MASTER'S RESEARCH – TAYLOR REGAN

Distributed Sensing for Condition-Based Prognosis of Fuselage Structures

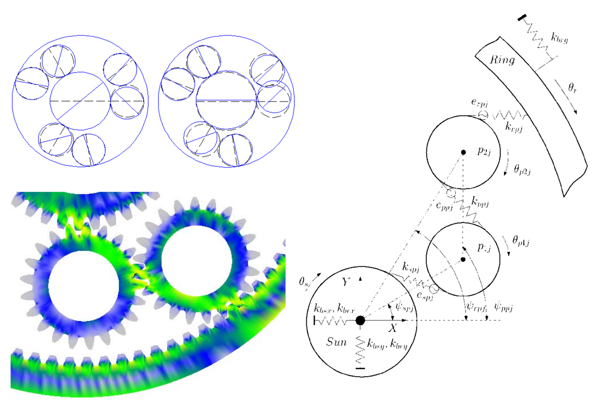


ABSTRACT

The development of a high fidelity analytical system for on-board prediction of the remaining useful life (RUL) of rotary and fixed wing aircraft/rotorcraft components will serve to strengthen the Army's structural health monitoring and prognostics capabilities. Objectives of this research include enhancing military structural health monitoring and prognostics capability, optimizing fatigue life of critical components, minimizing operational costs, and improved mission readiness by using a blend of computational modeling and data from a limited number of sensors relaying real-time system monitoring

MASTER'S RESEARCH – FYLER DYLAN

A Probabilistic Design Approach to Improve Sound Radiation Characteristics of Automotive Automatic Transmissions

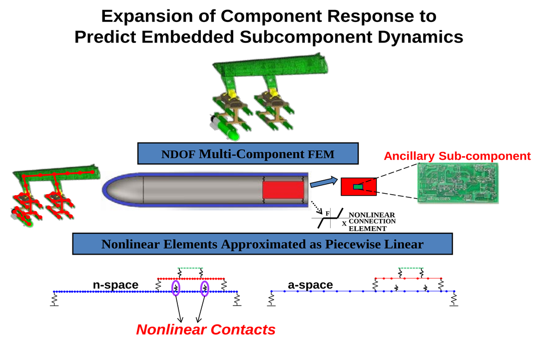


ABSTRACT

Existing gear sets can theoretically be optimized for sound reduction through the adjustment of design parameters while maintaining original design constraints of speed reduction, space consumption, durability, and load transmission. Double planetary gear sets specifically provide an excellent case for optimization due to having considerable amount of design options. Computational modeling of gear sets to determine the internal excitations in the system can be accomplished in various ways. Lumped parameter models are the most basic, simplifying the gears as rotating and translating masses and the meshes between gears to equivalent stiffness. Deformable body models utilize a contact model in combination with finite elements to determine deflections of gear teeth within the system. Due to double planetary gear sets having significantly more potential configurations than their single planetary counterparts, Design of Experiments (DOE) is necessary to generate a finite set of models that accurately represent the entire design space. Utilizing the results from these models, multivariate data analysis can be employed to better understand the effects and interactions of various design parameters.

PHD DISSERTATION – SERGIO OBANDO

Use of Expansion of Highly Reduced Order Models for Accurate Prediction Full Field Dynamic Characteristics in the Forced Response of Linear and Non-Linear Systems and Components

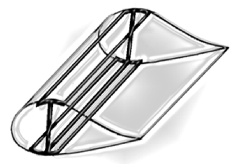


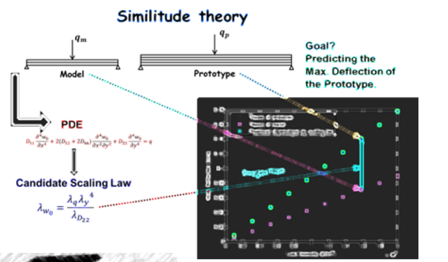
ABSTRACT

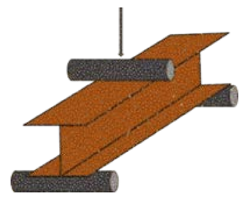
A comprehensive framework for the use of reduction and expansion methodologies of components and system models is proposed for the full field dynamic characteristics in both linear and nonlinear forced response for both displacement and strain. Commercial finite element models of high resolution are simplified to a reduced space in which different configuration of forces, boundary conditions and connecting/coupling elements can be tested efficiently and without loss in the fidelity of the model. With the calculated component or system model response at a reduced set of points, expansion can be employed to return to the full space of the model and predict the response at all degrees of freedom of the system. Furthermore, the system component response can be expanded to predict the dynamics of complete systems with complicated subcomponent or cascaded configurations.

PHD DISSERTATION – MOHAMAD EYDANI ASL

Subcomponent Testing of Wind Turbine Blades using Scale Models





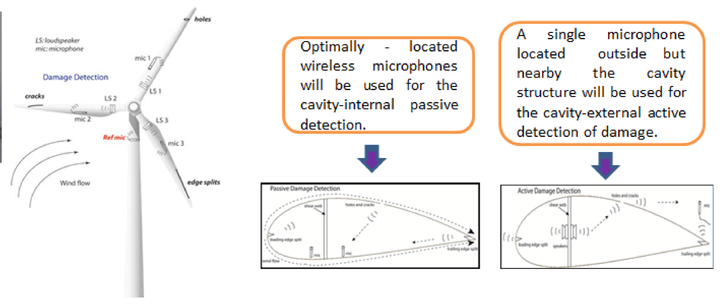


ABSTRACT

The mechanical behavior of new materials for wind turbine blades is initially characterized by using coupon testing and finally by full-scale blade testing. The coupon testing is not always representative of performance of the new materials, and full-scale blade testing is time consuming and very expensive. To bridge the large gap between coupon testing and a full-scale test, subcomponent testing is proposed as a cost-effective alternative. To design a meaningful scaled-down subcomponent emulating the structural conditions experienced in the full-scale component, it is proposed that similitude theory can be applied to the I-beam structure of a wind turbine blade involving spar caps and the shear web, to develop scaled-down models. Applicability of similitude theory in design of scaled-down composite structures is then investigated by manufacturing and testing the designed I-beams.

PHD DISSERTATION – RUKIYE CANTURK

Development of a Novel Acoustic-Sensing Based SHM Technique for Wind Turbine Blades

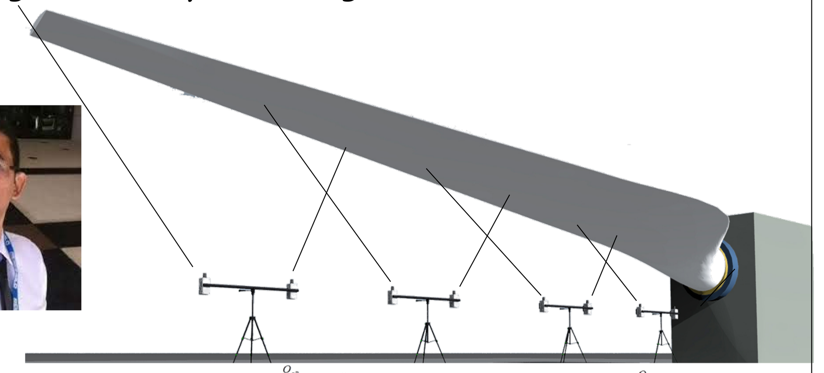


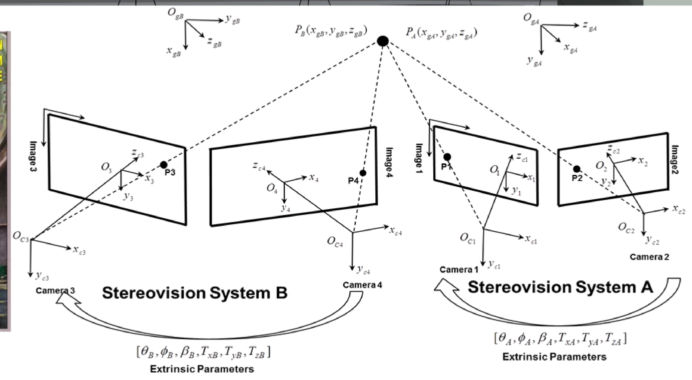
ABSTRACT

Modern wind turbine blades consist of composite airfoil shaped structures that form a hollow acoustic cavity. Because of continually varying aerodynamic forces, gravitational loads, lightning strikes, and weather conditions, blades will experience leading and trailing edge splits, cracks, or holes that are currently not detectable except by visual inspection or post blade failure. Proposed research will examine the use of wireless sensing approach from distributed points for detecting defects of wind turbine blades, while they are rotating in operation. Subscale wind turbine blade will be used for purpose of damage detection, identification and localization of the blades. Experimental measurements, computational modeling and analytical approaches to predict failures of wind turbine blades will be integrated. In order to handle an of the drawback of wireless sensing technique in terms of energy supply, distributed algorithms for wireless sensing network will be developed.

PHD DISSERTATION – PEYMAN POOZESH

A Multi-Camera Stereo DIC System For Extracting Operating Mode Shapes of Large Scale Structures



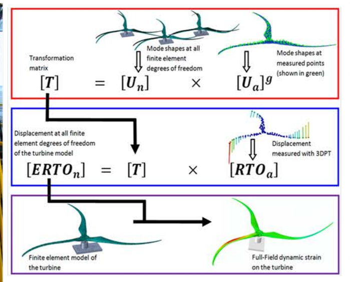


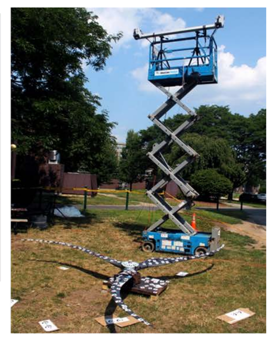
ABSTRACT

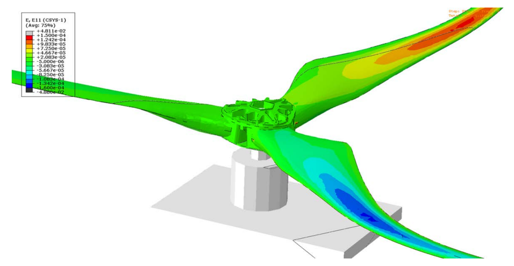
Stereo photogrammetry and three-dimensional (3D) digital image correlation (DIC) have recently received attentions for the collection of operating data on large wind turbine blades due to their non-contacting, rapid, and distributed measurement capability. Unlike conventional methods that only provide information at a few discrete points on a wind turbine blade, photogrammetry can provide a wealth of distributed data over the entire structure. One of the challenges with using a camera pair to observe a structure is the limited field of view. Because wind utility-scale turbines are so large and the physical limitations within a blade test facility, a single pair of DIC cameras may not be able to accurately measure the desired area of the structure. Thus, in order to perform a DIC measurement on a utility-scale wind turbine blade, it is desirable to couple several pairs of cameras to simultaneously measure the deformations of the entire blade. The measured deformations of each measured section of the blade needs to be stitched together to extract the deformation for the entire blade. In this thesis, a multi-camera 3D DIC measurement is used to identify resonant frequencies and corresponding operating shapes of a utility scale wind turbine blade placed in a cantilevered boundary condition. The setup is composed of multiple pairs of synchronized stereo cameras in which each pair of cameras measures a part of the blade's deformation

PHD DISSERTATION – JAVAD BAQERSAD

A Non-Contacting Approach for Full Field Dynamic Strain Monitoring of Rotating Structures Using the Photogrammetry, Finite Element, and Modal Expansion Techniques





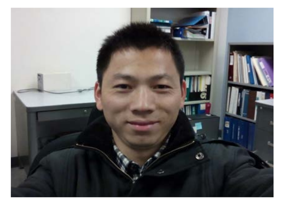


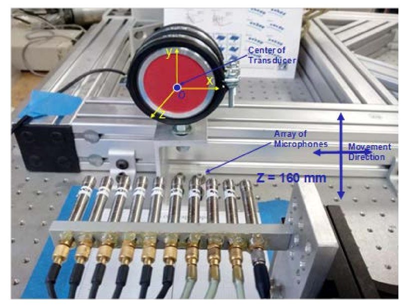
ABSTRACT

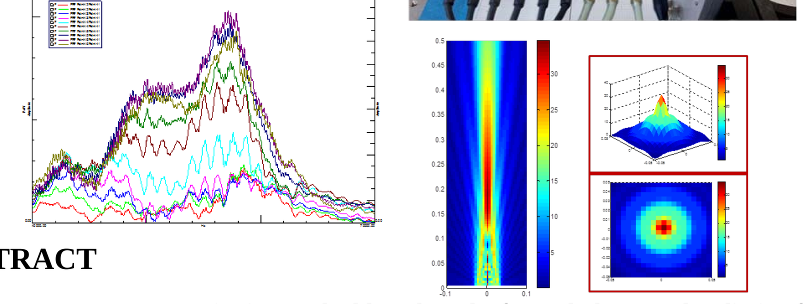
Within this work, an unique expansion algorithm was extended and combined with finite element (FE) modeling and an optical measurement technique to identify the dynamic strain in rotating structures. The merit of the approach is shown by using the approach to predict the dynamic strain on a small non-rotating and rotating wind turbine. A three-bladed wind turbine having 2.3-meter long blades was placed in a semi-built-in boundary condition using a hub, a machining chuck, and a steel block. A finite element model of the three wind turbine blades assembled to the hub was created and used to extract resonant frequencies and mode shapes. For the non-rotating optical test, the turbine was excited using a sinusoidal excitation, a pluck test, arbitrary impacts on three blades, and random force excitations with a mechanical shaker. The response of the structure to the excitations was measured using three-dimensional point tracking. A pair of high-speed cameras was used to measure the displacement of optical targets on the structure when the blades were vibrating. The measured displacements at discrete locations were expanded and applied to the finite element model of the structure to extract the full-field dynamic strain. The new expansion approach is able to extract dynamic strain all over the entire structure, even inside the structure beyond the line of sight of the measurement system.

PHD DISSERTATION – SONGMAO CHEN

Enabling Noncontact Structural Dynamic Identification with Focused Ultrasound Radiation Force





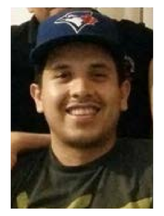


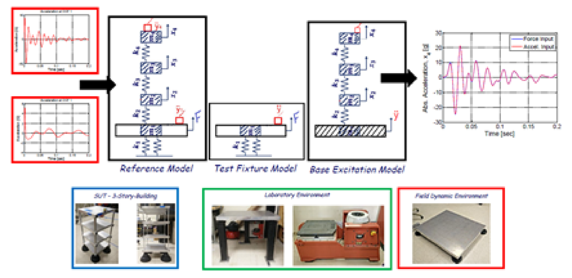
ABSTRACT

A laboratory noncontact excitation method based on the focused ultrasound radiation force, generated by an ultrasonic transducer is being exploited to excite vibrations within structures with size ranging from micro to macro and frequency range from a few kHz to 1 MHz, for potential applications in modal testing. However, the inability to monitor the real time acoustic radiation force prevents this approach from being used as a practical technique for measuring the frequency response functions (FRFs) in modal testing. Thus, this research focuses on the acoustic modeling, mapping, acoustic radiation pressure and force monitoring using both traditional microphones and novel point-type fiber optic pressure sensors theoretically as well as experimentally by means of state-of-the-art simulation and testing tools like MATLAB, Polytec Scanning Vibrometer and LMS Test.Lab. Modal testing applications are to be conducted and deeper understanding of this noncontact excitation technique is to be acquired.

PHD DISSERTATION – JESUS REYES

Shock Response Spectrum Synthesis to Compensate for Test Fixture Dynamic Coupling Effects



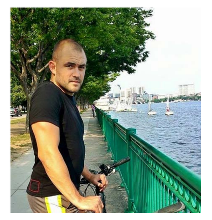


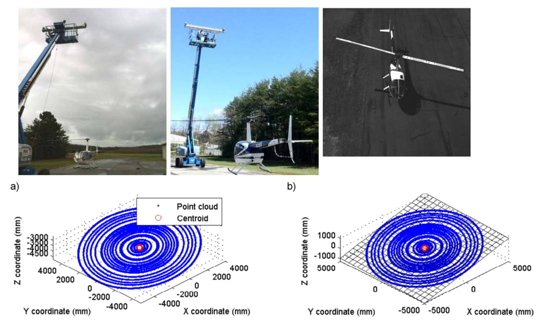
ABSTRACT

In order to account for the resonant behavior of any shaker system while exciting a test article, a novel approach is proposed which will allow the test engineer to accurately use the Shock Response Spectrum method for test specification and environment characterization. The technique is based on impedance modeling and frequency based substructuring theory. Frequency Response Functions of the shaker system and test article, disconnected from each other, are used to modify the acceleration input profile of the shaker system. The proposed technique will compensate for the dynamic coupling effects between the test article and the shaker system.

MASTER'S RESEARCH – TROY LUNDSTRUM

Operational data collection and analyses of the main rotor of a Robinson R44 Helicopter



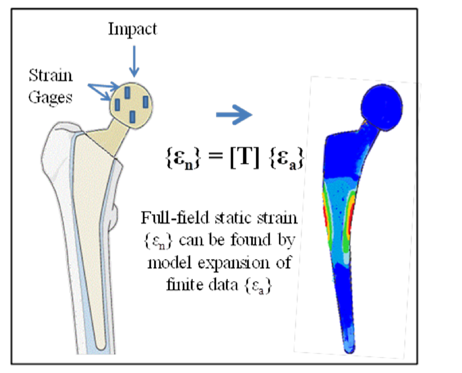


ABSTRACT

Stereophotogrammetry in conjunction with three-dimensional point tracking (3DPT) algorithms has proven to be a highly robust measurement technique when used to perform dynamic measurements on small, rotating systems. This measurement technique can be scaled up to much larger systems and has several desirable features for helicopter and wind turbine measurement applications that include: 1) it is non-contact and doesn't require the use of roll rings or slip rings for signal transmission, 2) the applied measurement targets have a negligible effect on the aerodynamics, mass or stiffness of the structure, and 3) position data can be readily collected on many hundreds of points over what is capable using conventional multi-channel data acquisition systems and transducers. A field test was conducted in which operating data was collected on the main rotor of a Robinson R44 helicopter in both grounded and hovering operating conditions. The first part of this work describes the experimental setup and data acquisition process of the test performed and the second part of this work presents some of the results including blade dynamics and extracted operating deflection shape information for a Robinson R44 Helicopter.

PHD DISSERTATION – TINA DARDENO

Model Mapping, Strain Expansion, and Damage Detection as a Methodology for Monitoring Femoral Implant Insertion during Cementless Total Hip Arthroplasty

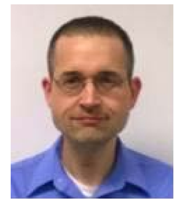


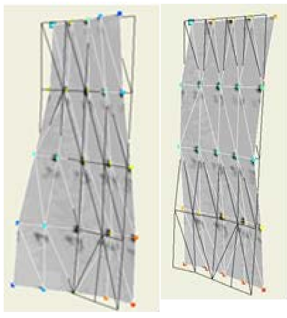
ABSTRACT

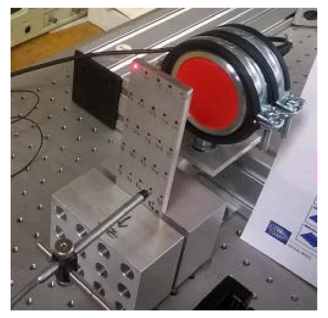
When a young, active, or heavy person requires hip replacement surgery, orthopedic surgeons typically opt for cementless technology which allows the bone to heal directly to the prosthesis. After removing the femoral head, the surgeon reams the femur to an area slightly smaller than the implant and then press-fits the implant into the femoral canal. Residual stresses from the press fit are required for the implant's stability and the magnitude of these stresses is critical. An implant is properly seated when the stresses are high enough to prevent micro motion of the implant but small enough to avoid femoral fracture. Currently, no device exists to objectively assess implant stability intra-operatively. Surgeons must instead rely solely on their clinical experience to determine seating. To supplement the surgeon's expertise a methodology will be developed using vibration analysis with analytical modeling coupled to strain measurements using digital image correlation (DIC) of exposed regions of the implant. This methodology will form the basis for the design of a real-time interface that will monitor insertion and seating of a cementless femoral implant.

PHD DISSERTATION – PATRICK LOGAN

Calibration of Non-Contact Force Excitation





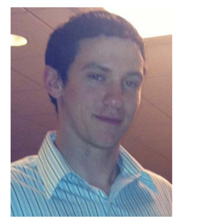


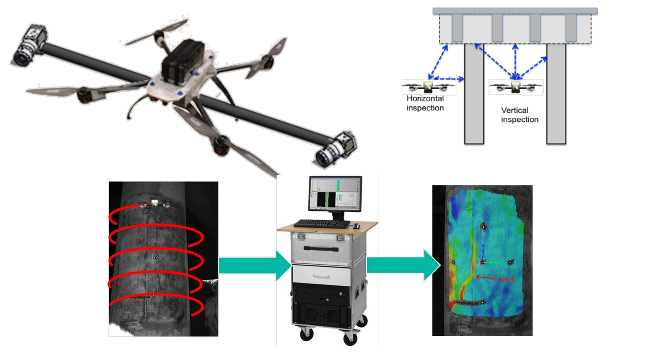
ABSTRACT

Use of non-contact excitation via ultrasonic transducer permits excitation of higher frequencies not typically reached by traditional excitation methods. While quantification of the input force is necessary for characterization of the dynamic behavior of a structure, non-contact excitation is problematic, as it cannot be measured via traditional force transducers. However, use of frequency response functions obtained with traditional excitation methods may be compared with frequency response functions obtained from non-contact excitation to determine an appropriate calibration by which force and driving voltage may be related. Additionally, force estimation techniques relying on measured responses and calibrated frequency response functions may be used to estimate the associated input force power spectra .

MASTER'S RESEARCH – DANIEL REAGAN

Autonomous UAV Bridge Inspection with 3D Digital Image Correlation





ABSTRACT

As the average age of the civil infrastructure (i.e. bridges, railways, and tunnels) continues to increase; the frequency and comprehensiveness of inspection must fullfil the modern demand. New structural health monitoring systems must be developed that are quantitative, non-destructive, and cost effective. Three-dimensional (3D) digital image correlation (DIC) has been used to quantify surface strain and crack growth in civil applications. 3D DIC is capable of acquiring high-accuracy large area surface strain, displacement and geometry profiles. These profiles can then be stitched together to generate a complete integrity map of the area of interest. Unmanned Arial Vehicles (UAVs) have emerged as valuable resources for positioning sensing equipment were a human presence would be hazardous or inefficient. Acquiring the images necessary for DIC from a UAV increases the speed of the measurement process and offers increased accessibility. The implementation of autonomous flight paths enables a simple and consistent measurement process. The combination of autonomous flight with 3D DIC and other mobile measurement systems has the potential to be a highly valuable and effective civil inspection platform.

Dr. Peter Avitabile
peter_avitabile@uml.edu

Dr. Chris Niezrecki
christopher_niezrecki@uml.edu

Structural Dynamics and Acoustic Systems Laboratory

http://sdasl.uml.edu/

Dr. Murat Inalpolat
murat_inalpolat@uml.edu

Dr. Zhu Mao
zhu_mao@uml.edu