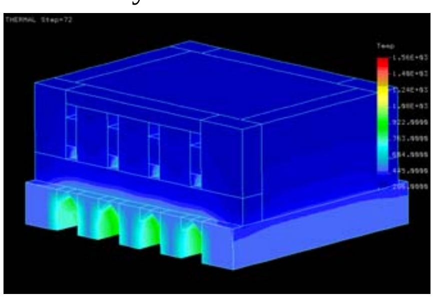
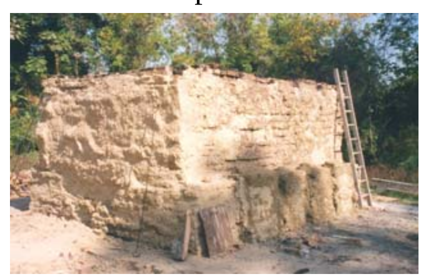
# *Recent Undergraduate NDE Projects at W&M*

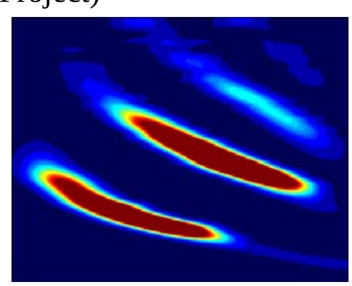
1. **Chandler Amiss, *Nondestructive Bond Strength Measurements of Aerospace and Automotive Structures***
   Modern aircraft designers would like to increase their use of adhesively bonded joints, because of the many advantages they have over mechanical fasteners and welding. However, until there is a reliable way to monitor nondestructively the strength of bonded joints, their use will be limited in primary load bearing structures. Most NDE methods measure stiffness, not strength. Chandler explored the use of full-field digital photoelasticity for nondestructive measurements of bond strength. By applying a known load to a joint in a hydraulic load frame, and by using photoelasticity in combination with finite element analysis to measure strains in the joint, the effective stress strain curve can be constructed for the joint. By watching for the point where the behavior begins to deviate from linearity, she was able to predict the ultimate strength of the joint without damage. (Funded by Virginia Space Grant Consortium.)

2. **Daniel Reid, *Thermographic Measurements and Finite Element Simulations of Temperature Distributions in the Colonial Williamsburg Brick Kiln*** (Senior Honors Thesis)
   In this project Dan explored the use of infrared thermography for monitoring the internal temperature distribution of the Colonial Williamsburg Brick Kiln during firing. He packaged a laboratory IR camera system to allow video infrared measurements to be taken at the site during the two weeks when this historically accurate kiln was fired. He digitized the videotape of the external surface temperature distribution, and used the resulting digital temperature maps in conjunction with his finite-element model of heat transfer in the kiln to correlate surface IR features to internal temperatures. In previous years, a series of thermocouples were used to monitor the internal temperatures, but these were considered to be "historically inaccurate" because the wires protruding from the kiln were "non-colonial." Infrared cameras, on the other hand, look like the kind of camcorders that tourists carry, so thermographic measurements do not interfere with the historical interpretation mission of the Colonial Williamsburg Foundation.



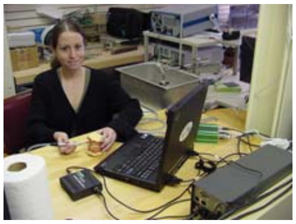


3. **Kari van Tassel, *Joint Time-Frequency Analysis of Ultrasonic Signals*** (NSF REU Project)
   Ultrasonic signals are typically analyzed in either time domain (RF waveform) or in frequency domain (spectrum). The time domain tells when the various echoes arrive and the spectrum tells the overall frequency content, but the "spectrogram" tells us when the various frequencies arrive. This knowledge can be especially important for dispersive guided wave modes or multi-component signals where it is difficult to distinguish the various echoes or modes of interest. Kari developed computer codes to analyze ultrasonic signals in this way, and she then tested her programs in a variety of experimental situations.



4. **Kevin Leonard, *Neural Network Expert System for NDE of Aircraft Structures*** (Senior Honors Thesis)
   Kevin explored the use of neural networks for automatically identifying the arrival times of ultrasonic Lamb wave modes in tomographic scanning systems. This measurement technique can be made fully automatic and portable for field use *if and only if* the thousands of arriving signals can be sorted out automatically and in real time. Since we know what the arrival times should be for unflawed plates, Kevin used several thousand measurements of these cases as his training set, and then proved his neural network on simulated aircraft structures with flaws.

5. **Jonathan Wood, *Ultrasonic Periodontal Probe Clinical Testing and Data Processing*** (NSF REU Project)



Jon went along for the very first clinical tests with the new ultrasonic periodontal probe system, and then analyzed the data comparing the ultrasonic measurements to controlled-force and hand probing. The enabling technology in this project is the artificial intelligence expert system that does all of the interpretation for the dentist or hygienist in real time. Jon's results helped to demonstrate feasibility and led to both a sequence of clinical studies and a series of improved prototype instruments.

6. **Michael Hsu, *Air Coupled Ultrasound B-Mode Imaging System for Robotics*** (NSF REU Project)

At a frequency of a few tens of kilohertz, ultrasound propagates reasonably well through the air over a distance of a few meters. Michael's summer project was to convert one of our existing ultrasound imaging apparatus, that we had built for a prostate cancer project, to an air-coupled ultrasound imaging system. Once the B-mode stacked-sector scanner was up and functioning with new transducers and electronics, Michael set about scanning a variety of things of interest in order to sort out the capabilities of this type of "range finder" for imaging and security screening applications.

7. **Betina Chan, *FIELD II Simulations of Prostate Cancer Ultrasound Array Probes*** (Undergraduate Research)

As a Computer Science major and Biology minor, Betina wanted undergraduate research experience that covered both areas but gave her exposure to some things not part of her coursework. During her Junior and Senior years here she developed a computer simulation system that predicted the B-mode images that would result from various combinations of phased-array ultrasound probes and prostate phantoms. Betina's simulation package allows us to do the engineering trade-off studies necessary in designing or specifying the performance of new ultrasound phased-array probes. Because these probes are inserted either into the rectum or via a catheter up the urethra, it's pretty important that the both work well and be as small as possible.

8. **Daniel Bowring, *Helical Lamb Wave Ultrasound Tomography of Cylindrical Tanks*** (NSF REU Project)

Guided ultrasonic waves can be used to inspect large area structures where the particular regions of interest are inaccessible. As a modification of a technique we've developed for inspecting aging aircraft, Daniel investigated application to the type of rusty old cylindrical storage tanks that contain the byproducts of nuclear weapons production. Because of the large numbers of the tanks and they way that they are stored, Lamb wave tomography is one of the only ways that they can be inspected rapidly and thoroughly enough. Daniel performed laboratory experiments on half-scale tanks in order to sort out the surprisingly complicated physics of the measurements.

9. **Kevin Rudd and Crystal Bertoncini, *Ectogenous Robots*** (NSF REU Projects)

The goal of this research is to equip mobile robots with arrays of different kinds of imaging sensors—along with the sophisticated processing algorithms necessary to interpret the sensor data—in order to provide them with more situational awareness than possible with visible-light machine vision systems. Kevin helped build the first Ectobot, ***rWilliam*,** with both a 50 kHz ultrasound pulse-echo scanner and a visible/near-IR camera and had fun driving it all about campus. Crystal later used this robot to explore ultrasound interaction with various types of hedges, bushes and such around the W&M campus.

**10. Alison Pouch, *Ultrasonic Classification of Emboli,*** (NSF REU and Honors Thesis)

Alison developed a sophisticated mathematical model of the interaction of medical ultrasound with bubbles and other emboli in the bloodstream, which resulted in algorithms to allow a new medical device to more accurately size emboli during cardiac surgery. Some fraction of people undergoing heart bypass surgery aren't quite right mentally afterwards, due to emboli blocking blood flow to parts of the brain, but the new EDACS device developed by a local company can now detect and size emboli during the surgical procedure.

**11. Danielle Dumond, *Mobile Robot Sensor Fusion*** (Senior Thesis)

Danny's work involved exploring the usefulness of thermal infrared (IR) imaging for robotic navigation. Our second Ectobot, ***rMary,*** has an IR camera which reflects off a 45-degree mirror to image the heat patterns of objects in front. Using our knowledge of the recent temperature, weather, etc. along with an understanding of the physics of how various everyday objects (trees, fences, brick walls, hedges, etc.) store and radiate heat, we define abstract features that can be extracted automatically via computer image processing from the IR imagery. Assessment of what an object might be is then done in some abstract mathematical feature space. Oh, and by the way, it works in perfect darkness.

**12. John DuChateau, *Using Ultrasound in Concealed Weapons Detection*** (NSF REU & Senior Thesis)

Since the unfortunate events of September 11, 2001, the scientific and security communities have focused on finding different and accurate ways to detect weapons and explosives concealed on a person's body. Current technology in that field includes x-rays and metal detectors. In John's experiments, he explored using air-coupled ultrasound as an alternative to these two detection methods. The advantage of ultrasound over metal detection is that ultrasound does not need the object being examined to be ferromagnetic; it can detect materials regardless of their magnetic properties. It also offers a cost-competitive alternative to x-rays and does not involve ionizing radiation. In these experiments, John set out to prove that ultrasound can be used to detect concealed weapons.

**13. Brian Walsh, *Non-Linear Acoustic Concealed Weapons Detection*** (Undergraduate Research)

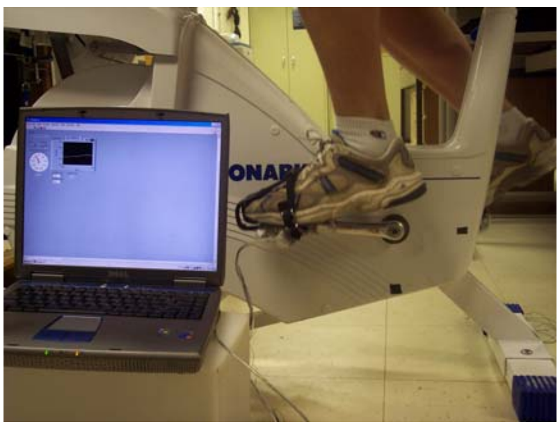
Brian's work involved development of a nonlinear acoustic concealed weapons detector using sound waves to interrogate a person at large stand-off distances via a sound beam created with a parametric array and directed onto a person. The parametric array sends out a very narrow sound pulse which scatters from the targets. Any back scattered acoustic energy is captured with a parabolic microphone and then digitized and recorded as a waveform. The structure of the backscattered energy will differ from a person with and without a hidden weapon.

Parametric arrays work by emitting high powered ultrasound waves that transition to lower frequencies because of nonlinear and absorption effects as the acoustic waves propagate. The nonlinear effects allow one to create a very narrow sound beam that can deliver the acoustic energy over large distances. Traditional air-coupled transducers have very narrow frequency bands that only allow single frequency tone-bursts. In contrast, parametric arrays have a broad frequency band that allows the initial waveform to contain a range of frequencies. In addition, the lower frequencies produced by the nonlinear propagations will penetrate layers of clothing more effectively than the higher ultrasound frequencies.

**14. Corey Miller, *Intelligent Structural Health Monitoring*,** (Senior Thesis)

The purpose of this project was to evaluate a promising technique for the structural health monitoring of aluminum airplane stringers. By sending guided ultrasonic waves throughout the length of a stringer, we are able to examine the structural health of the aluminum. We have recorded waveforms produced with two different transducers in both an incremental milling and an accelerated corrosion sequence, and have thoroughly analyzed the milling waveforms. In order to interpret the signals received from the transducers we used a dynamic wavelet fingerprinting technique which provides us with a simple visual way to view areas of interest within the signal. We found that we are able to accurately extract mode arrivals from the fingerprint images using both a nanopulser np3 and a toneburst source along with shear transducers in SV mode at 1MHz. Using these mode arrivals, we were able to produce group velocity values that agreed with values determined from the measured thickness values to within 4% accuracy.

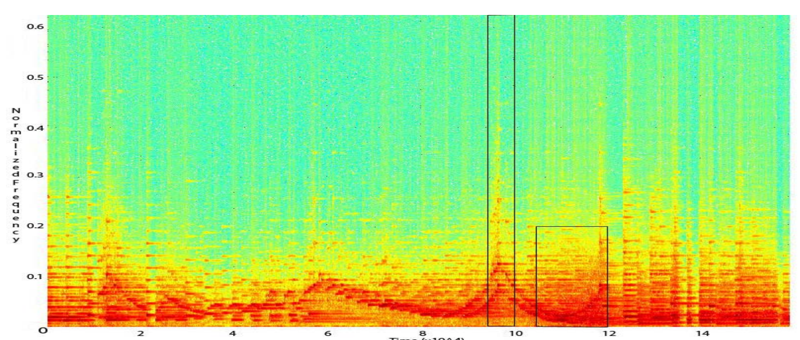
**15. Mark Cohey, *A Gage for Measuring Pedal Forces on a Stationary Bicycle*,** (Senior Thesis)



We investigated, created, and tested a device used to measure the pedal forces on a stationary bicycle. Such devices have uses in the medical, biomechanical, and sports sciences. This study encompassed researching previous devices to determine the most effective technique, building a device capable of retrieving useful data, and testing the device in a live experiment with human test subjects. Initial research found that most previous designs created pedals that could measure forces with high precision, but usually involved costly components or bulky computers. The primary focus on the experimental design was to create an effective device that not only took force measurements, but that was small enough that it could be incorporated into a non-stationary bicycle and low cost enough that it could be reproduced easily and available for larger studies.

16. **Jori S. Byrne-Diakun, *Automatic Repair of Physical Flaws in Recorded Music*,** (Senior Thesis)

Recording music in any form often produces artifacts that are not pleasing to the ear. Reducing these artifacts is the focus of millions of dollars in research for music companies every year. However, despite this research, there is still a considerablevolume of work that requires special attention, and historic non-commercial recordings are often never cleaned up enough to be sold, or even provided, to the general public because of the great amounts labor each recording demands. The goal of our research is to develop an automated process to clean up the damage to this piece of human history.




*Applied Science is an interdisciplinary graduate department which offers M.S. and Ph.D. degrees in the physical and biological sciences. Courses are offered cooperatively by the core faculty of Applied Science along with affiliated faculty from the Departments of Biology, Chemistry, Computer Science, Mathematics, Physics, and the Virginia Institute of Marine Sciences (VIMS), as well as from the NASA Langley Research Center (LaRC) and the Thomas Jefferson National Accelerator Facility (Jefferson Lab). In Applied Science we use the tools, the techniques, and the understanding involved in a wide range of sciences in order to solve complex scientific and technical problems. The Department has state-of-the-art facilities in: (1) theoretical and computational analysis of physical and biological systems, (2) cellular and systems neurophysiology, (3) materials synthesis and characterization of small molecules, polymers, inorganics, and composites, (4) modification and evaluation of interfaces, (5) processing of materials and surfaces, and (6) imaging technology and theory from nano to planetary scales. While Applied Science does not offer an undergraduate major, several courses in the department are particularly suitable for undergraduate students of physics, mathematics, chemistry, computer science, and biology. An undergraduate minor in Applied Science is offered with a track in Materials Science.*

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