2015

Research Brief

Brophy, Chris

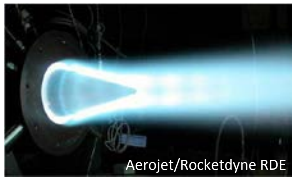
Naval Postgraduate School (U.S.)

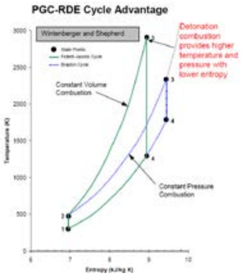
Rocket Propulsion & Combustion Lab

Pressure Gain Combustion
Rotating Detonation Engines (RDE)

Dr. Chris Brophy, David Dausen, Lee Van Houtte
Students LT Culwell, ENS Khol, Robert Wright, Andrew Chaves

Motivation



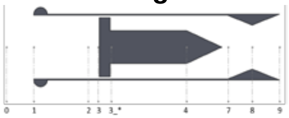


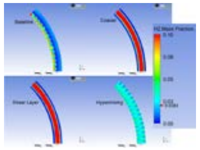
* Pictures from Aerojet Rocketdyne and GE Aviation

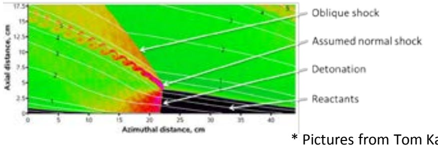
- **Utilize detonation-based combustion to extract increase thermodynamic cycle efficiency for work/thrust apps.**
- **Higher Enthalpy combustion for greater fuel efficiency**

Mission

- **Maximize net thrust**
- **Minimize total pressure losses**
- **RDE thermodynamic modeling**
- **Computational Modeling and experimental testing**

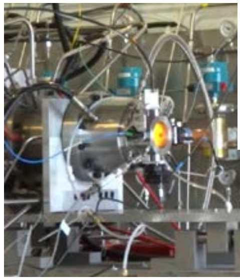




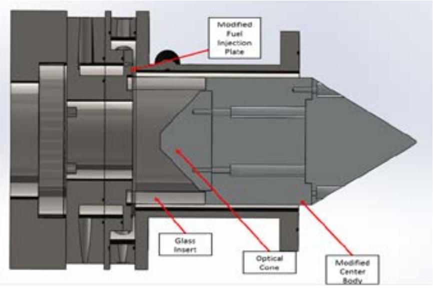


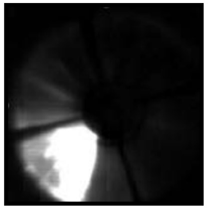
* Pictures from Tom Kaemming and NRL

Advanced Diagnostics



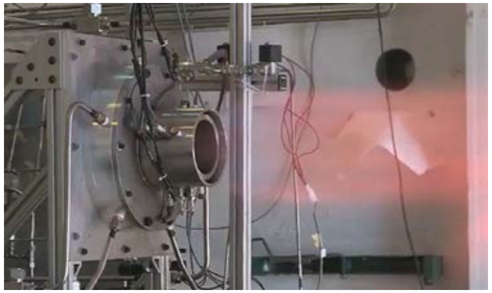
- **Advanced optical diagnostics**
- **Enthalpy (50+ kHz) measurements (TDLAS spectroscopy)**
- **Heat transfer**
- **Ion Gauges**
- **High frequency and average pressure (CTAP)**





Summary

- **Detonation based combustion has the potential to provide a substantial improvement in delivered performance and operability.**
- **Combustor/turbine coupling for power extraction or combustor/nozzle for thrust applications.**
- **Research and collaborative efforts:**
  - **Air Force Research Lab,**
  - **Naval Research Lab**
  - **NASA**
  - **Aerojet-Rocketdyne,**
  - **United Technologies**
  - **GE Aviation**
  - **National University of Singapore**



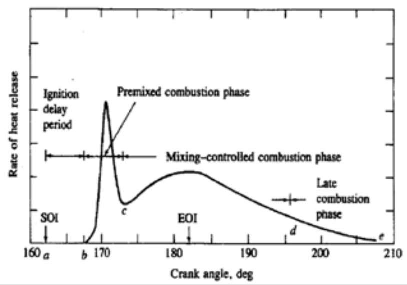
Rocket Propulsion & Combustion Lab

BioFuel Combustion

Dr. Chris Brophy, David Dausen, Robert Wright, Lee Van Houtte
Students ENS Andrew Rydalch, ENS Warren Fisher

Motivation

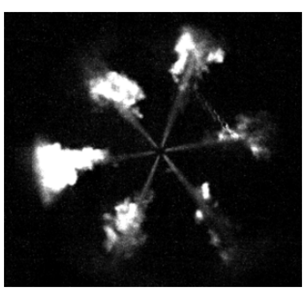
- Ignition delay testing of alternative fuels for Navy applications. Conventional F76 ignition results compared with those for Hydroprocessed Renewable Diesel (HRD)/F76 blends.
- Utilize Navy relevant injectors and conditions



Approach

- Simulate top-dead center conditions of compression stroke utilizing preburn technique Ethylene/Air) to achieve appropriate pressure and temperature
- Inject fuel at pressures and rates representative of Navy marine diesel operation.
- Combustion chamber scaled for use on EMD-based systems (8 in diameter).

Advanced Diagnostics

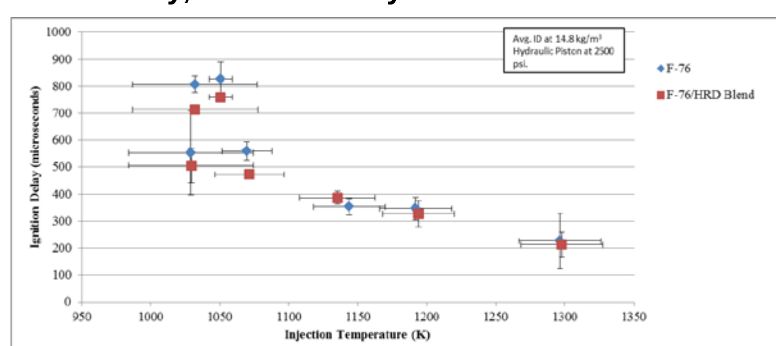


Ignition of Fuel Jets

- Ignition delay is measured optically with high-speed (50 kHz).
- Fuel seeded with fluorescent dye and excited with 532nm laser.
- Combustion determined through chemiluminesence imaging of CH* emission.
- Particle sizing accomplished with a Phase Doppler Particle Anemometer (PDPA).

Summary

- Deviations of ignition delay values only observed at low temperatures for F76/HRD blend for injectors evaluated.
- Novel optical measurement devised minimizing delay of conventional means (Pressure and Temperature Only) and fidelity of Ignition delay
- Research and collaborative efforts occurred between NPS, U.S. Naval Academy, and University of Wisconsin.

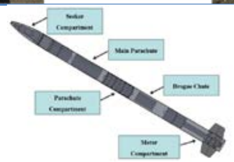


Missile Design

Dr. Chris Brophy, David Dausen, Andrew Chaves
Robert Wright, Lee Van Houtte
Students enrolled in ME 4704

Rocket Propulsion Combustion Lab

Motivation



- **Provide students with a fully hands on design project**
- **Design to fly in less than 12 weeks!**

Mission

- **The rocket is designed as an actively guided missile demonstrator to intercept an aerial target**
- **This demonstrator teaches the design process as team effort to design, fabricate, and successfully fly and recover this missile demonstrator system**
- **Students are able to evaluate the tracking software and control algorithm on future flights to validate simulations and provide feedback on the delivered performance of the system**
- **With modest sponsorship this platform could be modified to provide an advantage in the field to rapidly reduce the effectiveness of multiple incoming enemy assets**

Technical Information

Rocket Hardware

- **Dimensions:** 13’ long x 7.75’’ diameter
- **Weight:** 75 lbs
- **Power:** Cesaroni M1300 rocket motor (400+ lbs Thrust), internal batteries

Quad Copter Target

- **Dimensions:** 4’ long x 3’
- **Altitude:** 2000 ft AGL
- **Cameras**: x2 (GoPro Downward + Contour Upward)

Software

- **Matlab:** Image processing for real time optical target tracking
- **Parachute Electronics:** Raven3 and MARSA4 altimeters, wireless remote control black powder igniter
- **Cameras:** x2 (Contour Nose cone + one aft)

Summary

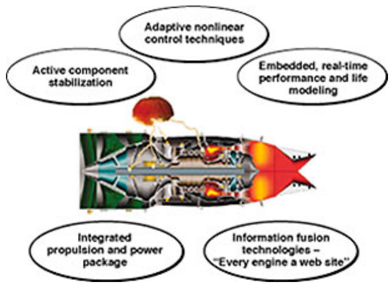
- **This class is available to NPS Students (Military and Civilian)**
- **This class is fast paced design, test, fly in an aggressive schedule indicative of today’s research programs**

Turbopropulsion Laboratory (TPL)

Transonic Axial Splittered Rotor (TASR) Development

Profs. Garth Hobson and Anthony Gannon
PhD Student CDR Scott Drayton and MSc Student Lt Michael Lehrfeld

Motivation

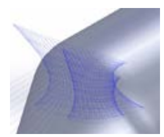


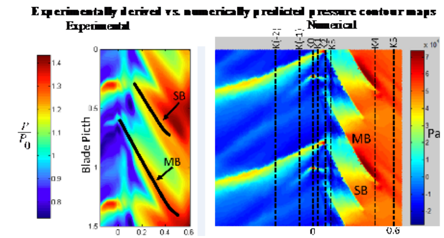
- Advanced Heavy Lift Vertical Take-Off and Landing Craft
- Advanced Variable Cycle Engines

Mission

- Design, build and test a transonic axial splittered rotor for performance testing
- Develop a design methodology based on off-the-shelf software

Geometry mods in minutes instead of hours



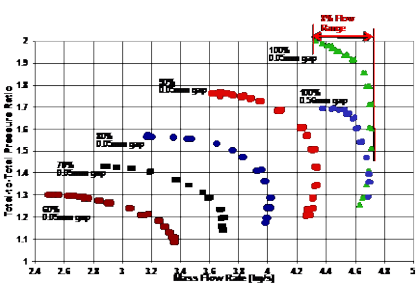


- Understand a mitigate tip-leakage flows by measuring the case-wall pressures over the TASR rotor with fast-response Kulite pressure transducers

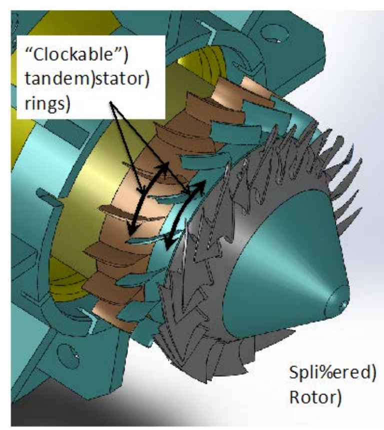
Technical Information

Performance

- Pressure Ration 2:1
- Mass Flow Range 8%
- Isentropic Efficiency 80%



Summary



- Highest pressure ratio for a single rotor at a tip speed of 495 m/s
- Impressive mass flow rate range
- Extensive data set of high-speed unsteady pressure measurements on the casewall
- Testing of the splittered rotor ahead of a tandem stator about to commence (Stage Performance)

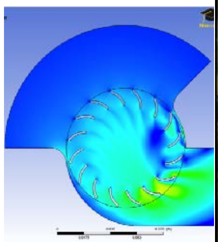
Turbopropulsion Laboratory (TPL)

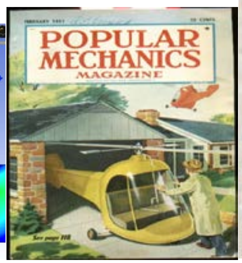
Cross-Flow Fan (CFF) Powered Vertical Take-Off and Landing (VTOL) Aircraft

Profs. Garth Hobson and Anthony Gannon
ENS Mike Martin

Motivation

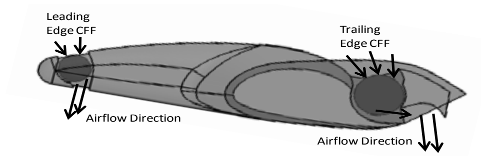
- NASA Personal Air Vehicle Development
- Temasek Defense Industries VTOL Project





Mission

- Design, build and test a CCF powered quad-rotor
- Maximize the propulsive efficiency of a CFF
- Develop a VTOL craft with fixed-wing performance in forward flight.

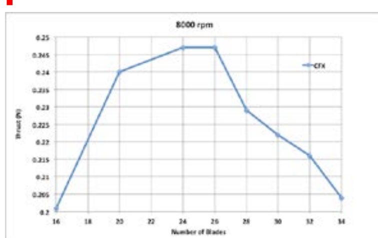


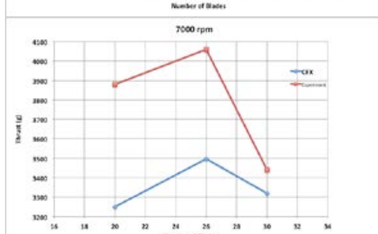
- Optimize the Thrust/Power ratio of a CFF.

Technical Information

Performance

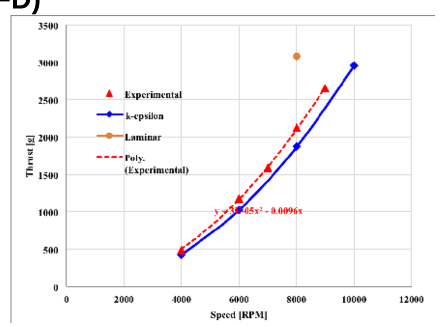
- Optimum 26-bladed rotor with 4” diameter
- Thrust-to-weight ratio 2:1
- Lightweight carbon-fiber construction

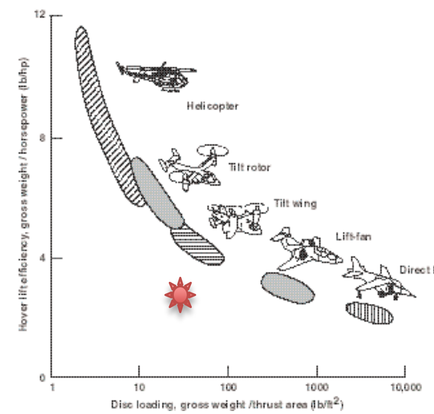




Summary

- First CFF powered quad-rotor flight (tethered) Feb 2014.
- Predicted 20-bladed performance with Computational Fluid Dynamics (CFD)





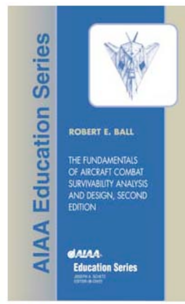
Center for Survivability & Lethality (CSL)
Aircraft & Ground Vehicle Survivability
Christopher Adams

Naval Postgraduate School
Center for Survivability & Lethality (CSL)

Motivation

The CSL was established to covers a wide range of topics in both survivability and lethality including:

- Fixed and rotary wing aircraft (manned and unmanned)
- Surface ships and submarines
- Ground vehicles
- Personnel



What is a Survivable System?

A system w/ the capability to avoid (low susceptibility, measured by $\mathbf{P_H}$) or withstand (low vulnerability, measured by $\mathbf{P_{K|H}}$) a hostile environment.

Keys to Success

- The NPS faculty have great expertise in the analysis, design for increasing the survivability and lethality of military platforms, weapons, and systems.
- NPS students are warfighters, and consequently they bring a level of knowledge, experience, and judgment to their research that is not available anywhere else

Survivability Enhancement Concepts

<u>Susceptibility Reduction (Avoid)</u>

1. **Threat Warning & Situational Awareness**
2. **Noise jammers and deceivers**
3. **Signature reduction**
4. **Expendables**
5. **Threat suppression**
6. **Weapons & tactics, flight performance, & crew training & proficiency**

<u>Vulnerability Reduction (Withstand)</u>

1. **Component elimination/ replacement**
2. **Component location**
3. **Component redundancy**
4. **Passive damage suppression**
5. **Active damage suppression**
6. **Component shielding**

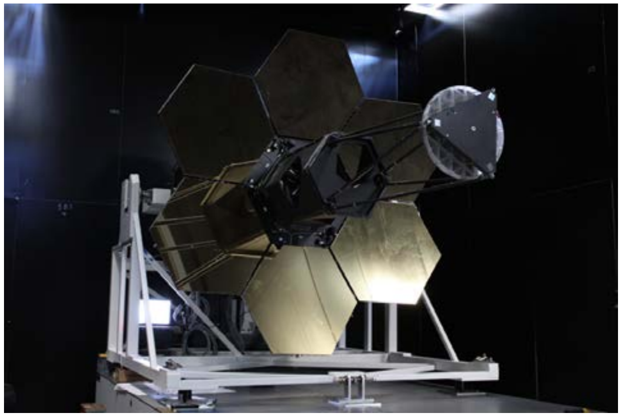
Segmented Mirror Telescope

Profs. Brij N. Agrawal, Jae Jun Kim

Students Maj. Matt Allen, LCDR Ernesto Villalba

Adaptive Optics Center of Excellence for National Security

Segmented Mirror Telescope



Segmented Mirror Telescope (SMT)

Objectives

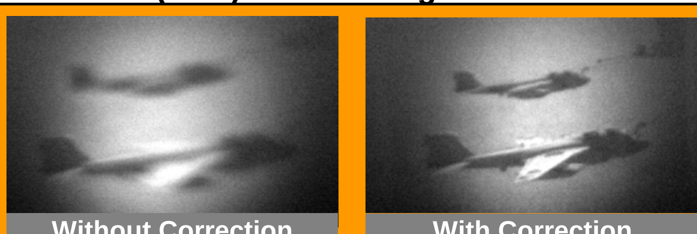
The objective of the research is to develop key technologies for large space mirrors to improve the capability of future imaging spacecraft to provide high resolution, persistent surveillance

Background

Achieving high surface accuracy of a large space mirror for high resolution imaging is very challenging. Key technologies for large aperture lightweight space mirrors need to be identified and developed

SMT Features

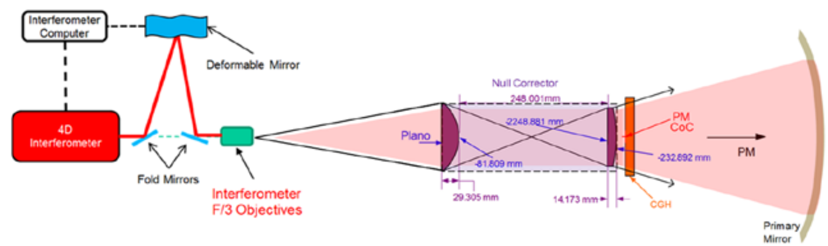
- 3-meter diameter with six 1-meter mirror segments
- Each segment is a actuated hybrid mirror with 156 actuators facesheet actuators (FSA)
- Mirror segments can be phased using 6 coarse control actuators (CCA) and 3 fine control actuators (FCA) on each segment



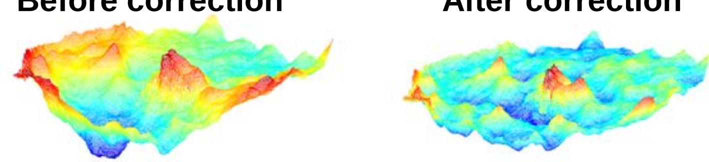
Imaging performance improvement with active mirror surface correction

Surface correction using a deformable mirror

Deformable mirror is added in the optical path



Before correction | After correction



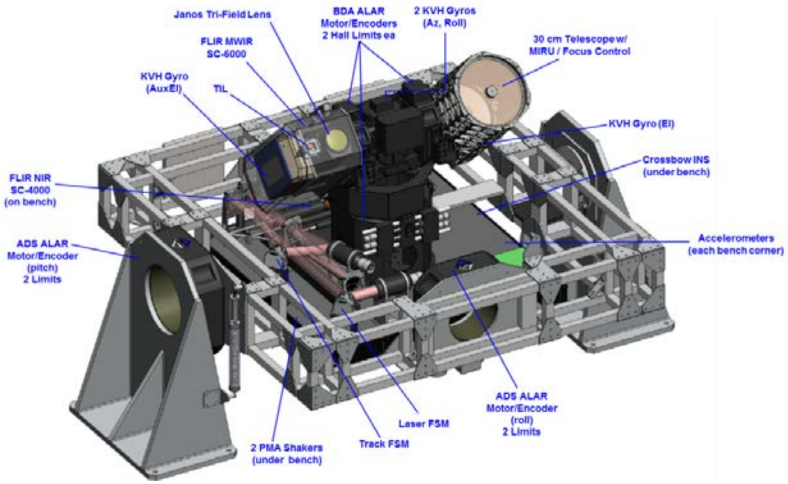
55% improvement in RMS surface error

High Energy Laser (HEL) Beam Control Testbed (HBCRT)

Profs. Brij N. Agrawal, Jae Jun Kim
Student LT Christopher Flores

Adaptive Optics Center of Excellence for National Security

HEL Beam Control Testbed



Objectives

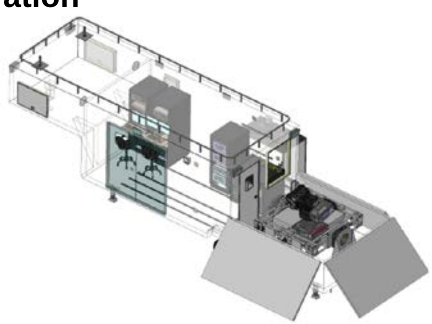
The objective is to develop HEL Beam Control Research Testbed for demonstration of optical beam control technologies for high energy laser systems.

Background

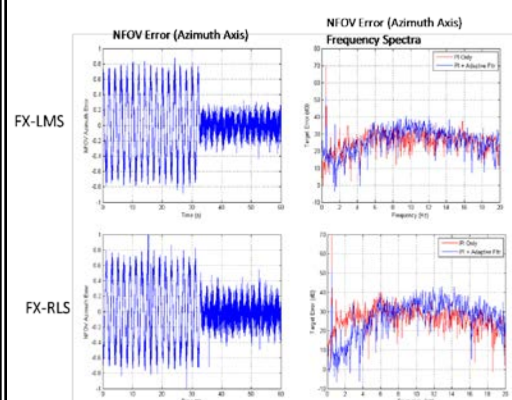
High Energy Laser system has many challenges in acquisition, tracking, pointing and atmospheric compensation. NPS is leveraging current Navy efforts in HEL beam control technology

Technical Approach

- Develop advanced beam control methods for acquisition, tracking, pointing, line-of-sight stabilization (jitter control), and adaptive optics
- Develop fieldable HEL Beam Control Testbed (HBCRT) for advanced beam control demonstration

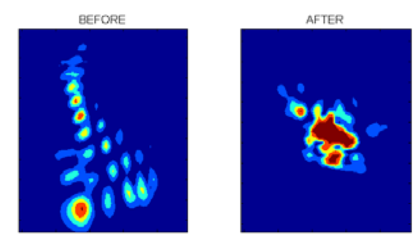


Optical Beam Control



Filtered-X LMS/RLS Adaptive Filter control reduces jitter

Atmospheric turbulence simulation using SLMs



Laser beam correction using adaptive optics

Fluid-Structure Interaction of Composites
Dist. Prof. Young W. Kwon, MAE
With many USN students

Multifunctional, Multiphysics, & Multiscale Research Laboratory (M^3 Lab)

Motivation

More composite ships…

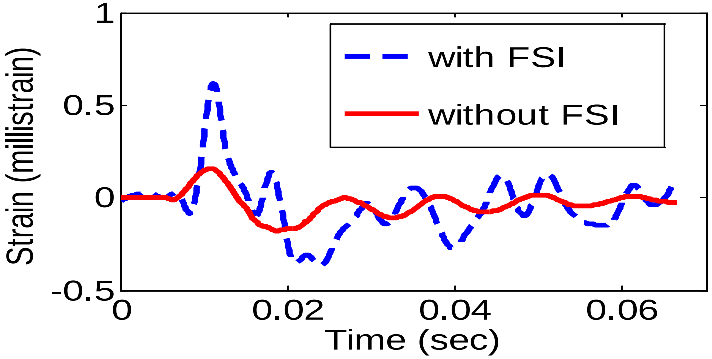
Research Objectives

To study vibrational characteristics of composite structures with Fluid-Structure Interaction (FSI) for dynamic response of marine structures.

Approaches

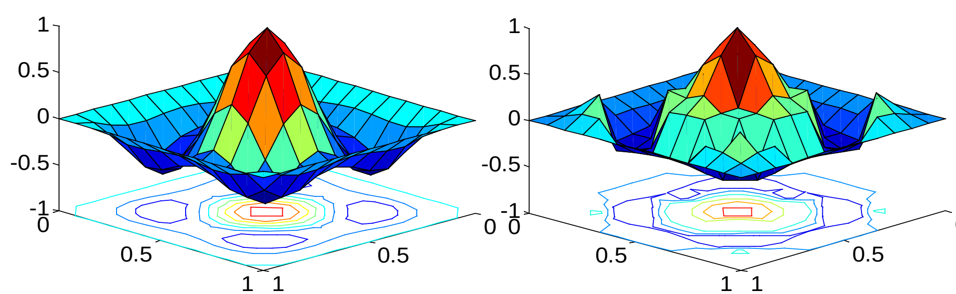
Compare and examine vibrational behaviors of composite structures submerged in water or air, respectively, using experimental and numerical techniques.

Results



Composite structure with FSI experiences much greater strains than that without FSI under the same impact loading

Results



Comparison of mode shapes without FSI (left) and with FSI (right) . (Please see the major difference near the corners of the clamped plate. Such a difference resulted in the drastic difference in strains)

Composite Patching on Cracked Ship Structure

Dist. Prof. Young W. Kwon, MAE
LT Aaron McGee, USN, LT Benjamin Hall, USN, LT Timothy Olson, USN

Multifunctional, Multiphysics, & Multiscale Research Laboratory (M^3 Lab)

Motivation

Research Objectives

(1) To develop analytical solutions to predict the expected service life extension with composite patching on cracked ship structure.

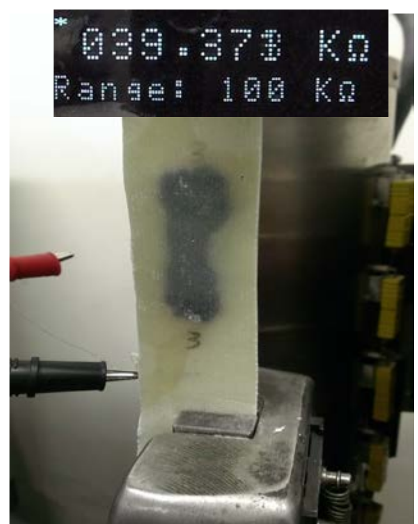
(2) To develop design guidelines for optimal composite patching.

(3) To develop multifunctional composite patches for service life extension as well as monitoring crack growth under composite patches..

Approaches

- Analytical, numerical and experimental techniques are used together to complement one another.
- Use of carbon nanotubes (CNT) in the composite patch for multifunctional purposes.
- Change in electric resistance in CNT is measured as crack grows.

Results



Aluminum structure side with crack

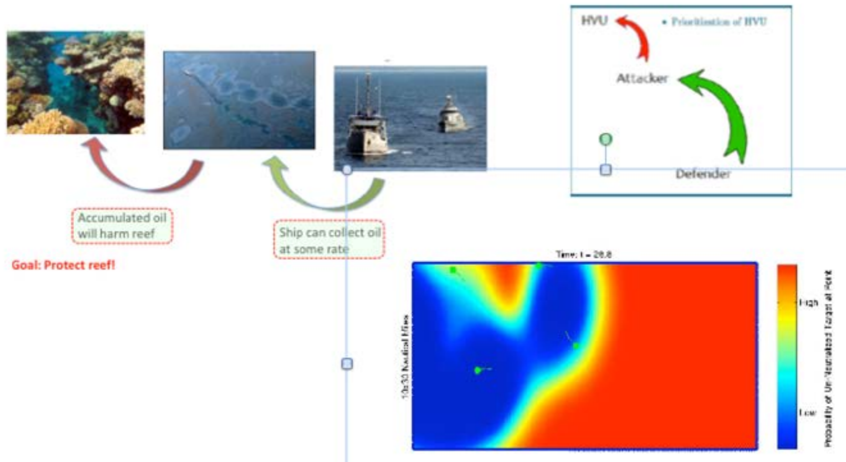
Composite patch side without crack

Maritime Force Protection and Herding using Autonomous Agents FY10-FY14

PIs: I. Kaminer, J.O. Royset, D. Horner
Naval Postgraduate School

Objectives

- Optimize search and detection of threats to maritime high-value units (HVU) and herding these threats away from the HVU
- Formulate class of generalized optimal control models, construct efficient discretization schemes, and develop offline and online optimization algorithms
- Explicitly address distributed uncertain nature of real-time detection and tracking problems



New application: The generalized optimal control framework can also be used to generate optimal trajectories for the ships cleaning up, for example, an oil spill. In this case the oil spill is modeled as an attacking swarm and clean up ships as the defenders of a coral reef

Technical Approach

- Mathematical optimization and control
- Novel class of models involving parameterized optimal control problems
- New implementable algorithms based on consistent temporal and spatial approximations, rigorous definition and construction of optimal discretization schemes
- New distributed tracking control algorithms with guaranteed performance

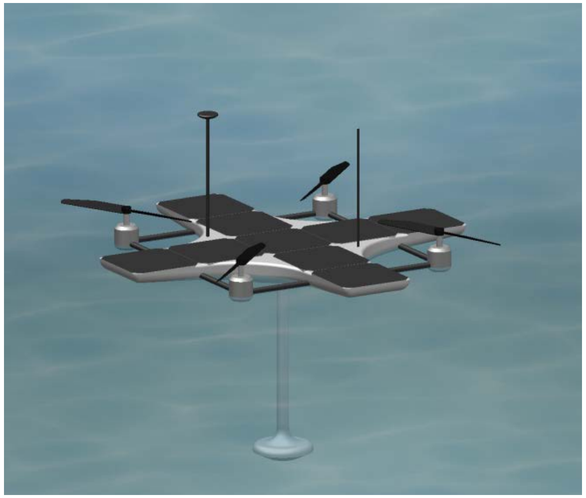
September 2014

Accomplishments

- Extended previous results to include parameter uncertainty in system dynamics
- New formulation of the herding problem using predator prey models
- Addressed curse of dimensionality of quadrature methods: Monte Carlo Sampling
- of the distributed pursuit guidance
- Used the new framework to address problems in
  - Environmental Cleanup
  - Optimal sensor placement
  - Navigation in uncertain environments
- Success is measured by new CONOPS

Solar Powered, Long Endurance, Hybrid Mobil Buoy for Persistent Surface and Underwater Reconnaissance

NAVAL POSTGRADUATE SCHOOL




Objectives:

Develop a water-tight, buoyant, self-righting multi-copter with a solar recharge capability, that can float on the ocean surface with a submerged sensor suite for passive or active sensing. The buoy would recharge batteries during sunlight hours allowing for continuous sensor use and occasional flights above the ocean surface for advantaged communications and/or relocation.

The key idea:

Combine benefits of low cost and agile autonomous multi-rotor capable of *lifting* a significant payload and carrying sufficient *computational* and *communication* capabilities with the *detection* capabilities of light weight passive sonar and high performance *solar panels* capable of charging the flying buoy in a matter of hours.

Key challenges: *Long distance communication* in rough seas requires significant elevation and stabilization of communication antennas. The ability to relocate acoustic sonar sensors rapidly to a required location is a desired tactical advantage not easily available at present.

Optimal conservation and expenditure of constraint power resources for propulsion and communication.

Technology thrusts: Solar and seawater-driven batteries, sensors, efficient comm. links, low power adaptive embedded computing and signal processing.

Applications:

- Undersurface warfare
- Marine habitat tracking
- Meteorology and Oceanography
- Pollution tracking

MAE M.Sc. Candidate: TBD

Key Participants (CAVR faculty, MAE):

K.D. Jones, V.N. Dobrokhodov, I.I. Kaminer

Key Deliverables and Milestones

Phase I - Proof of concept &platform design:

- Flyable platform suitable for water landing and takeoff under first manual and then autonomous control with positive buoyancy and self-righting stability in the water.
- Solar recharge system integration with a flight/recharge/flight demonstration.
- Autonomous launch, navigation and landing using an integrated autopilot and GPS navigation.
- Integration of passive acoustic sensors, data-logging and signal processing with pop-up and transmit flight mode.

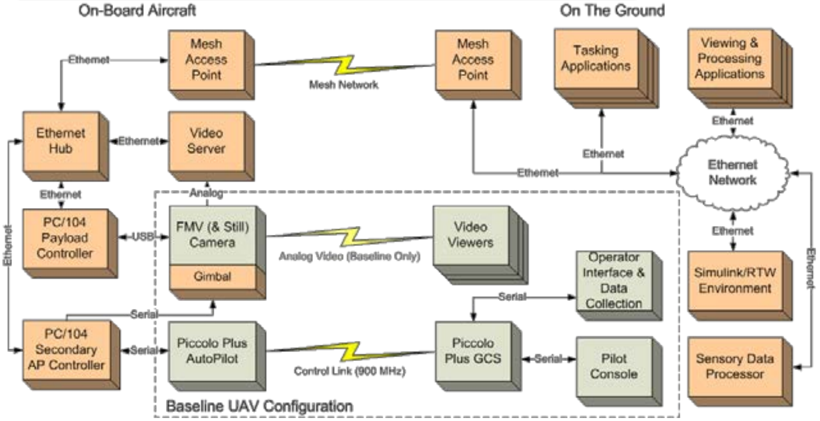
Phase II – Integration of the platform into application scenarios:

- Energy management algorithms for extended mission endurance
- Navigation and signal processing for objects detection and tracking
- Decentralized coordination for improved operation effectiveness

Patent pending

Cooperative Flight Control Prototyping System

Scalable IP-based architecture of single UAV



Key functionality of the system:

- Rigorous theoretical approaches to multiple UAVs path planning, cooperative control design and verification.
- Model-based approach to control design and integration that is driven by mission objectives.
- Focus on cooperative execution by heterogeneous UAVs
- Unified and modular IP-based Hw/Sw architecture.
- Adoption of advanced mathematical tools and methods for algorithms design and implementation.
- Ability to conduct rigorous flight verification and validation of multiple UAV missions in restricted airspace.
- Understanding of objectives in various applications.
- Theory and technical solutions feasible for integration in class-room environment.
- Rapid code generation and seamless integration onboard with feasibility constraints in mind.

POC: Vlad Dobrokhodov, vldobr@nps.edu; Kevin Jones Jones@nps.edu; Isaac Kaminer, kaminer@nps.edu

Objective: Provide verifiable means of design and in-flight validation of novel cooperative control strategies for multiple heterogeneous UAVs.

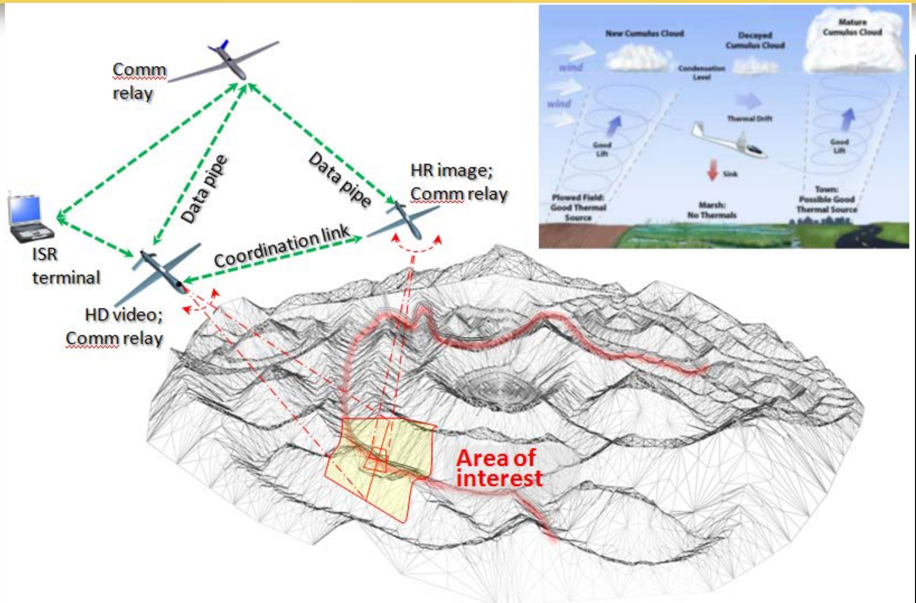
Capabilities:

Theory	Software	Instrumentation
• Coordinated path following robust to degraded comm. • L1 theory of fast and robust adaptation • Vision-Based Robust Target Tracking • Multiple agents path planning	• GNC development in MatLab/Simulink. • Autocoding and V&V tools. Hard/soft RT execution. • ROS/SPREAD messaging & comm. • Optimal use of CPUs with Linux integration	• Unified avionics setup. • Open architecture. • Self config. MANET. • Circuitry and electronics design for novel sensors and integration. • Rapid hardware prot. and 3D printing.

Fleet of heterogeneous UAVs and payloads

Improving Operational Effectiveness of Tactical Long Endurance Unmanned Air System (TaLEUAS) by Utilizing Solar Power

NAVAL POSTGRADUATE SCHOOL



Objectives: Develop a system of multiple cooperating autonomous gliders that harvest thermal and solar energy to achieve extended endurance that will be used to provide long duration network and communication coverage in a typical ISR mission.

The key idea is in developing and implementing onboard of tactical autonomous gliders a set of distributed coordinated energy sensing and accumulation algorithms that will significantly extend their flight endurance and thus reduce the need for external energy supplies while improving the efficiency of ISR and communication support.

Envisioned Scenario: A team of autonomous gliders is launched by the marines from a friendly area to provide ISR sensing along with network and communication coverage. The gliders use a combination of solar and thermal energy harvesting algorithms and instrumentation and remain airborne for extended time; for 3-5 days or as needed. When airborne, the gliders operate either in a distributed fashion over an extended area of operation, or they provide a more focused support for high-value local targets. The latter may include cooperative distributed sensing to achieve precision strike support, tracking of ground targets, convoy following, etc.

Key Deliverables and Milestones:

- Algorithms for integrated energy harvesting that determine the minimum number of gliders needed to cover a given area of operation
- A single integrated (solar+thermals) glider that can autonomously operate in a typical ISR scenario. This phase is underway currently supported by the ARL office funding.
- Multiple cooperative gliders in multiple day ISR mission -
- Publications at AIAA and IEEE conferences on autonomous systems

Key Participants (CAVR faculty, MAE):
Prof. K.D. Jones, V.N. Dobrokhodov, I.I. Kaminer

NAVAL POSTGRADUATE SCHOOL

AUV Operations in Extreme Environments: Under-Ice Operations

Center for Autonomous Vehicle Research
CAVR

Operational Objective:

- Incrementally gain experience with under-ice AUV operations in support of Navy interests in the Arctic, culminating in ICEX16 participation
  - REMUS and THAUS AUVs
  - AUV operations in support of science mission

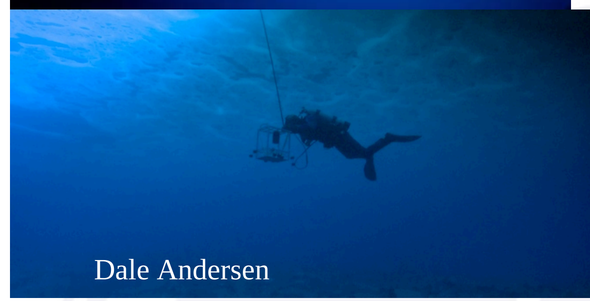
Technical Objectives:

- Investigate accurate, high-resolution 3D mapping to aid with navigation and obstacle avoidance for under-ice operations and AUV recovery.
- Investigate terrain-relative navigation for under-ice operations and AUV recovery.

Approach:

- Phased approach: Under-ice operations
  - Phase 1-2: Baseline (ice-free) and under-ice operations in known environment
  - Phase 3: Under-ice operations in unknown environment (in support of science mission)
  - Phase 4: Under-ice operations in support of Navy science mission (ICEX16)
- Investigate 3D mapping with prototype interferometry forward-looking sonar
- Investigate vision-based terrain-relative navigation


antarctica.gov.au


Dale Andersen


whoi.edu

Milestones:

- Complete Phases 1-2 in Nov 2014 and Feb 2015
- Mapping data collection: Feb 2015
- Real-time 3D map building: Aug 2015
- Under-ice operations at Lake Untersee, Antarctica Oct-Dec 2015

Collaborators: SETI Institute, BAER Institute

PI: Dr. Noel E. Du Toit (nedutoit@nps.edu), Dr. Douglas P. Horner (dphorner@nps.edu)

Robotic Diver Assistant

Operational Objectives:

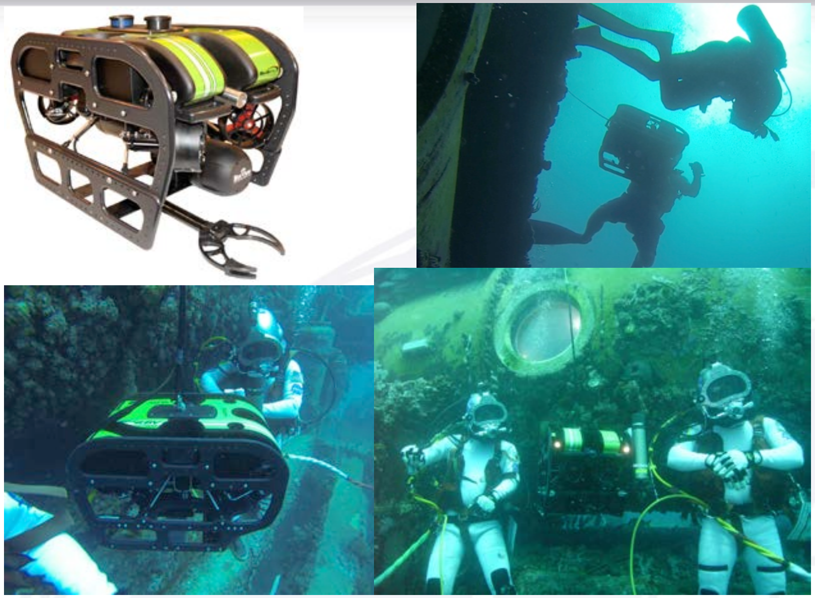
- Reduce need for human divers in high-risk environments
- Increase diver efficiency, effectiveness, and safety
  - when human divers cannot be eliminated
  - Force augmentation (no burden to divers)
  - Unobtrusive diver-robot control interface (when desired)

Technical Objectives:

- Develop suitable robotic platform
- Localization, sensing, communication, mobility
- Closed-quarters AUV operations (incl. mapping)
- Joint diver-robot operations (incl. stabilization)

Approach:

- Underwater localization
  - Terrain-relative navigation
  - Localization augmentation using active and passive sensors
- Underwater mapping
  - Mapping of 3D structures
  - Simultaneous localization and mapping (SLAM)
- Perception, communication
  - Novel emphasis on shorter-range, higher resolution underwater sensing
  - Short-range underwater communication
- Platform control, stabilization
  - Disturbance rejection
  - Adaptive control
  - Dynamic stabilization during intervention



Achievements:

- Platform development: 2012-2014
- Semi-autonomous operations: June 2014
- Autonomous operations: September 2014
- Active stabilization (adaptive control): December 2014

Collaborators:

- NASA JSC (NEEMO experimentation program, joint human-robot operations)
- SETI Institute, BAER Institute (Under-ice operations)

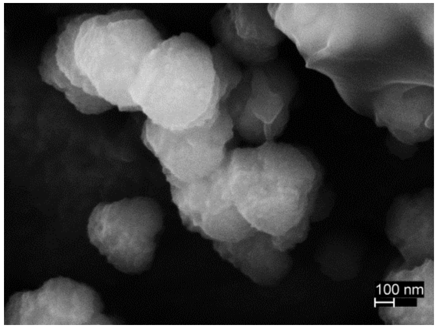
PI: Dr. Noel E. Du Toit (nedutoit@nps.edu)

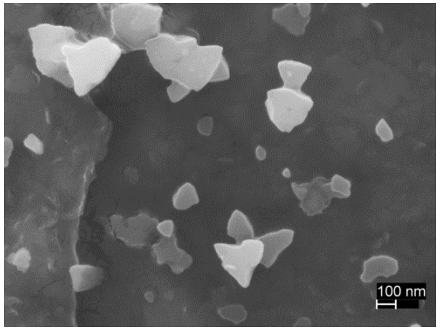
Characterization of Particles formed via Laser-Driven Hydrothermal Processing (RMJ2K)

Drs. Sarath K Menon, Claudia Luhrs (US Naval Postgraduate School)
Dr. Raymond P. Mariella Jr., (Lawrence Livermore National Laboratory)

Objective: To employ multiple state-of-the-art microscopy and analytical techniques to investigate the morphology, size distribution, crystal structure and microchemistry of particles produced by LDHP. Such information will provide insight into the fundamental mechanism involved in LDHP comminution of submerged samples and deliver further evidence of its applicability as new technology to enable nuclear forensics.

Method: LDHP is a newly developed process that uses laser pulses with modest energy density to dissolve a material while it is submerged in water. Here, a systematic study of the mechanisms involved in the process will be carried out by utilizing advanced methods of materials characterization to examine the process byproducts.





SEM micrographs of particulates formed during LDHP process (left). The shape and size of the particles is indicative of an aggregation process occurred over weeks after the sample collection. In contrast, quartzite particles are fragmented with diamond saw (right).

Status of effort: Quartzite and concrete have been comminuted using the LDHP process while submerged in room-temperature [RT] water by LLNL collaborator. The product generated, ultrafine particles, has been separated from the supernatant using a centrifuge and analyzed at NPS. Initial studies corroborate that the morphological characteristics of the product are different than the ones observed when samples are prepared by other methods.

Personnel Supported: 2 faculty at NPS, 2 senior scientists at LLNL, 3 US active military students conducting thesis work.

2013-2014 Publications & Meetings for the group: 12 peer-reviewed publications, 5 theses, 12 participations in symposia, 5 patents.

Year 1: Controlled comminution of quartz and concrete samples using diverse process conditions and development of protocols for products analysis.
Year 2: Studies on amorphous/glassy materials
Year 3: Application of the methods developed to structures similar to the ones analyzed during nuclear forensics.

Funding Profile

$149922 12/1/14-11/30/15 $150K Dec 2015-Nov 2016
$150K Dec 2014-Nov 2017

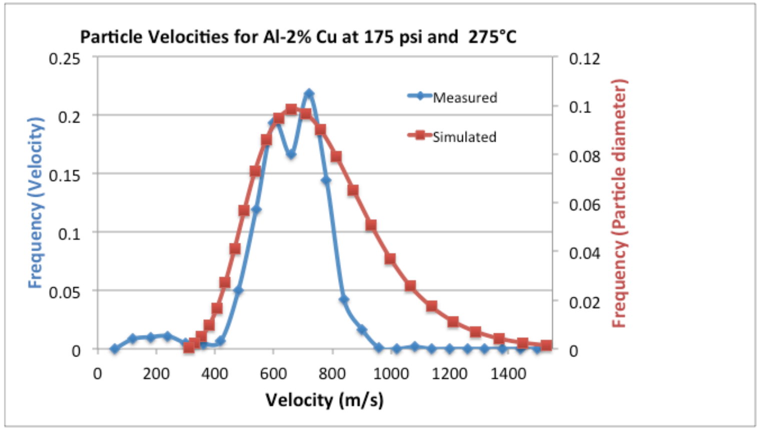
Contact information

S Menon: skmeno1@nps.edu 831-656-2551
C Luhrs: ccluhrs@nps.edu 831-656-2568
R Mariella Jr: RayMar47@llnl.gov 925-422-8905

Field-Based Residual Stress Measurements and Cold Spray Deposition for Corrosion Repair (RMH9M)

NPS/SK Menon, Univ. Alabama/ / L.N. Brewer, NSWCCD / J. Wolk, NAWCAD / F. Lancaster

Measurement and Simulation of Particle Velocities during Cold Spray Deposition



Objective/Description

We will use the Al-Cu binary system to understand the fundamental relationships between powder particle composition and microstructure and the resultant microstructure and mechanical properties of cold spray coatings in this alloy system.

Payoffs/Key Technologies

- Repair of Al-Cu aircraft structures
- Science-based approach to understanding alloying on cold spray deposition
- Basic physics of particle impact and adhesion

Schedule/Milestones

- Task 1: Process and Characterize Al-Cu Powders –*will finish by EOY 2015*
- Task 2: Determine Powder Microstructure- Cold Spray Deposition Relationships. *Critical velocity experiments completed.*
- Task 3: Comprehensive Characterization of Processing-Microstructure-Mechanical Property Relationships.
- Task 4: Single Particle Impact Experiments and Simulations. *FY2015 milestone met.*
- All milestones for FY2014 completed. Program is on schedule.

Funding

Total Funding – $530,000 Program Total
FY15 – $160K
FY16 – $160K

POC's

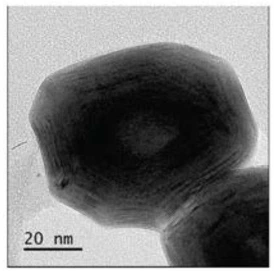
Sarath Menon/Luke Brewer/Fred Lancaster / Jennifer Wolk– NPS/AIR4.3.4 / NSWCCD
Kevin Little-NPS Comptroller

Fracture Mechanisms in Nanomaterials

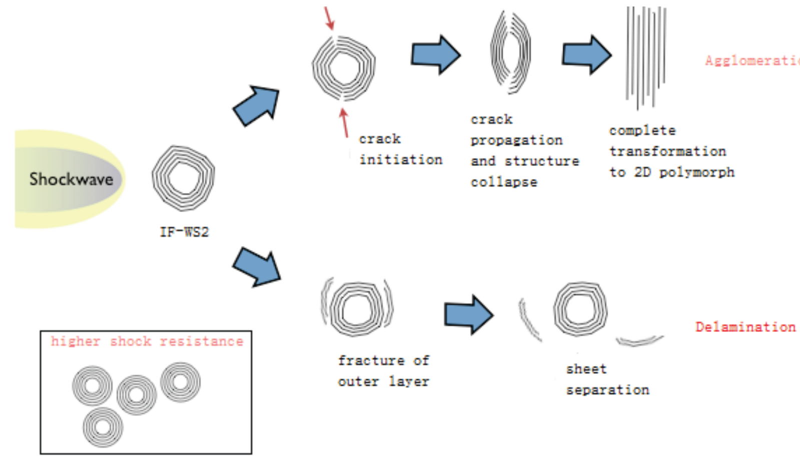
Claudia C. Luhrs, Associate Professor

Project Goal:
Vulnerability of Nanomaterial Based Systems

Study the structural characteristics of a material that has fractured to understand how materials fail then proceed to make changes to the design and prevent encountered failure modes

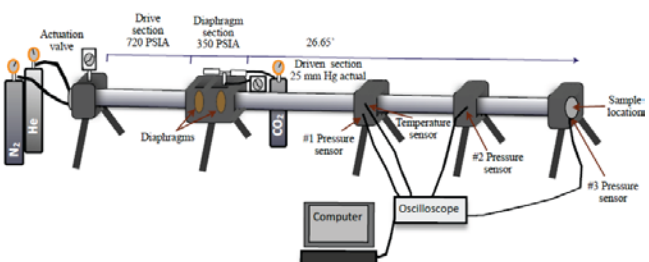


IF-WS2 particulates are recognized for their potential not only as lubricants but also as structural nanocomposites and shock absorbers

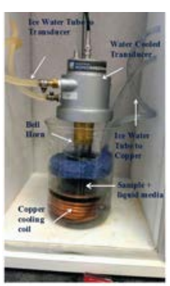


failure mechanisms found in inorganic fullerene-type tungsten disulfide (IF-WS2) nanoparticles treated with diverse pressure loading methods

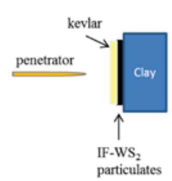
a)



b)

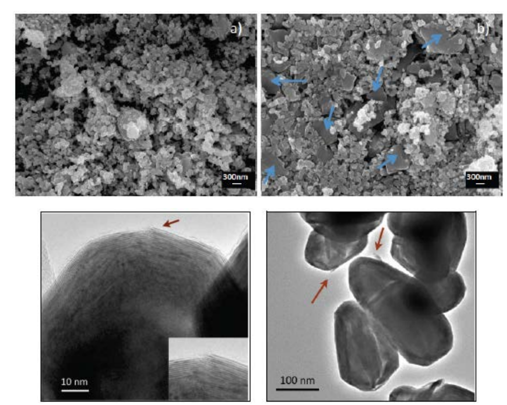


c)



Fracture mechanics at the nanoscale:

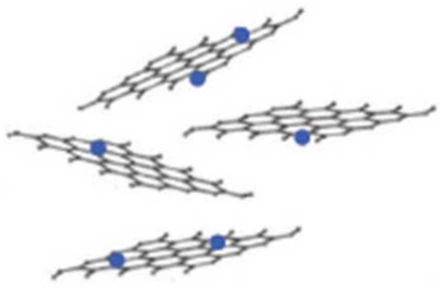
Defect sites act as stress concentrators independently of how energy is delivered: shock being applied in fractions of a second, or over long periods of time, as an isotropic or non-isotropic event, as a single occurrence or by cyclic treatment.



Nitrogen Doped Graphene Electrodes For Supercapacitor And Battery Applications

Claudia C. Luhrs, Associate Professor

Project Goal:
Understand the effects of nitrogen doping on the microstructural features, stability and performance of graphene when used as electrode in batteries and supercapacitors



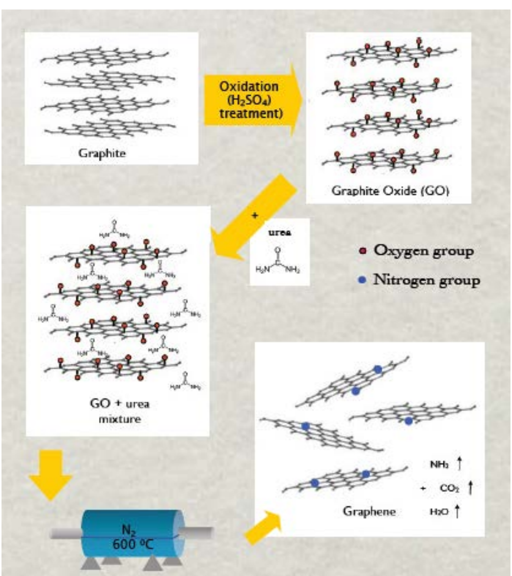
Graphene electrode characteristics:
- *High values of accessible surface area*

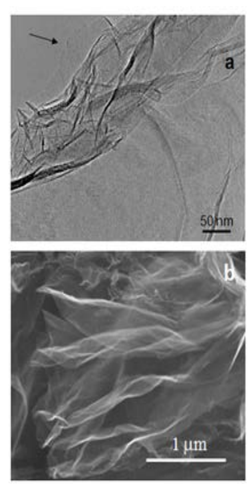
Nitrogen doped graphene:
- *Increased conductivity*

Tasks:

SEM and TEM - characterize the microstructural features of the products.
EDS and EELS - evidence of the inclusion of nitrogen in the structure.
XRD patterns and Raman signal - peak shifts are considered consistent with the diverse nitrogen contents.
BET – examine effects of doping levels in the surface area values of the products
TGA analysis – study nitrogen doped graphene stability at high temperatures.

Reductive Expansion Fabrication Process





Advantages of RES method of production:

i) Generates extra gaseous species that add to the volatile oxygen groups leaving GO to aid the thermal exfoliation,
ii) Promote the reduction of the GO precursor and
iii) Provide the nitrogen to be inserted in-situ as the Graphene structure is created.

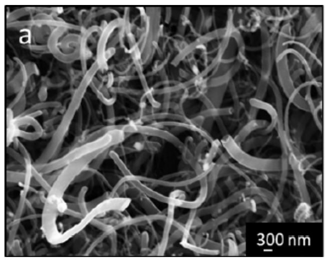
Milestones:

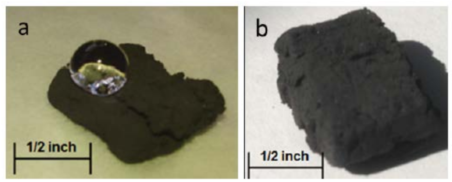
i) Produced N-doped graphene with controllable amount of nitrogen
ii) Demonstrated the improved capacitance of the doped materials when compared un-doped samples
iii) Achieved longer cycle life and higher thermal stability

Low Density Carbon Fiber Foams

Claudia C. Luhrs, Associate Professor

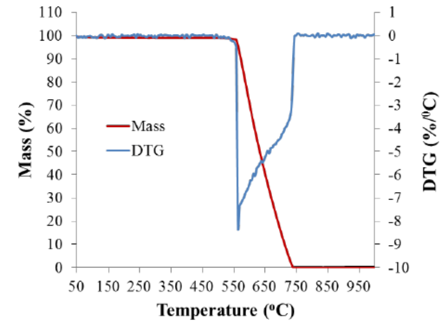
Project Goal:
Develop lightweight carbon fiber foams for personal protection applications



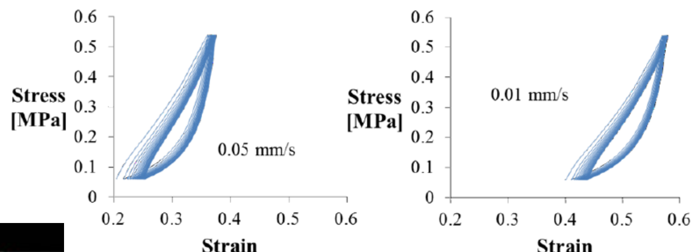


Thermal Stability:

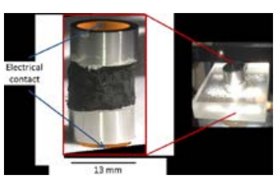
- Stable up to 550 degrees C (200 more than polymeric counterparts)



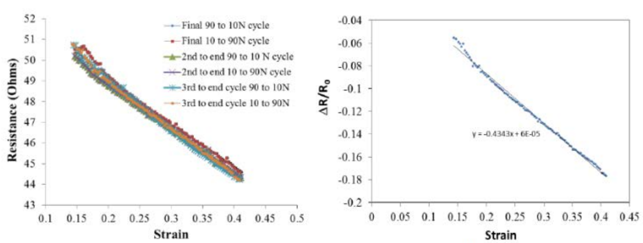
Mechanical properties:



(a) (b)



Electrical properties:



(a) (b)

Foam Characteristics:

- viscoelastic material (no polymer included, purely inorganic)
- high conductivity
- low specific gravity
- high temperature stability
- hydrophobicity

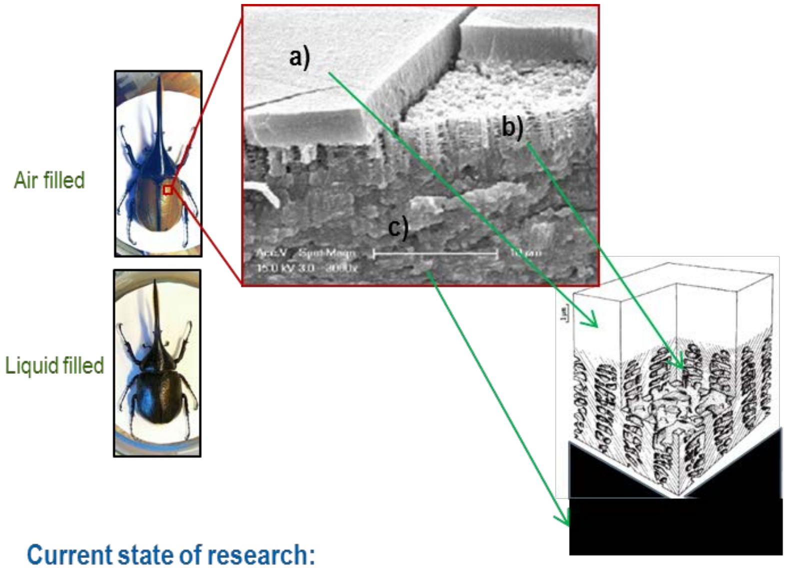
Potential applications:

- shock absorber, sensing element, electrode material, filter or absorbent membrane, and low drag surface, among others.

Mechanical and Optical Characterization of Submicron Biostructures. Bioinspired Advanced Composite Development

Claudia C. Luhrs, Associate Professor

Subject of study:
Hercules Beetle,
Dynastes Hercules



Current state of research:

- Optical properties of the elytra derive from highly-tunable submicron geometric shapes rather than from the nature of the materials used to make them. The change of color of the *Dynastes hercules* under varying humidity is due to the penetration of liquid into a 3D porous structure: The outer cuticle layer is transparent (a), underneath porous layer is yellow (b) and the inner cuticle (c) is black.

-The structure of the Hercules beetle reflects an end product of engineering experience gained through evolution: strength and flexibility combined.

Our goal:

- Study the microstructural characteristics of the cuticle and correlate those with mechanical (completely unknown) and optical properties.

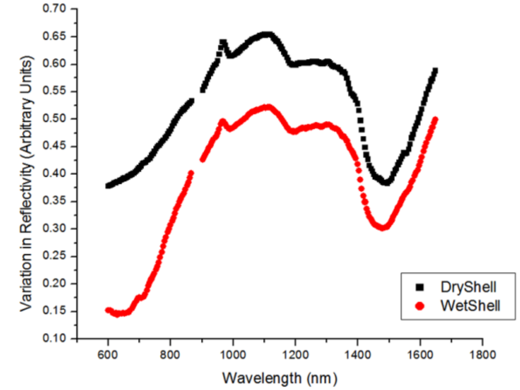
-Apply the lessons learned from biomaterials to develop composites that could mimic the properties observed: tailor made fiber composites.

- Long term objective: fulfill the need of providing lightweight materials of Naval Relevance.

Areas of military interest:

Body armor and camouflage.

Synthesizing a composite material with properties similar to the structure of the porous layer should result in a very effective camouflage material for visual and SWIR.



Anodized titania nanotubes: