JMEM AIR TO SURFACE TASKS 3,8,16

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: U.S. Army Material System Analysis Activity and Naval Postgraduate School

OBJECTIVE: To improve delivery accuracy methodology and to develop a real time DA capability.

SUMMARY: The first part of the project was to develop a spreadsheet that would compute delivery accuracy of unguided weapons. This was accomplished with the assistance of LT T. Smith. The second part was to begin translating this methodology into a c++ environment capable of being integrated directly into JAWS. The third task related to the analysis of accuracy for the AGM-65 Maverick missile, and the calculation of accuracy parameters for the JAWS program.

THESES DIRECTED:

Smith, T., "Real Time Computation of the Delivery Accuracy for Air Launched Unguided Weapons," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Bombing Accuracy, Weaponeering

REVIEW AND IMPLEMENTATION OF MOUT DOCUMENTATION AND METHODOLOGY

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: U.S. Army Training Analysis Command-Monterey

OBJECTIVE: Review Army and SOF documents dealing with methodologies applying to MOUT.

SUMMARY: This was a small start up project to review available documentation for a proposal into the application of the Acquire target acquisition model to the MOUT environment. An FY02 proposal was submitted and subsequently approved.

THESES DIRECTED:

Leach, D., "Weaponeering Small Boats," Masters Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Target Acquisition, MOUT, Combat Modeling

WHITE PAPER ON THE JTCG/ME TRAINING AND EDUCATION REQUIREMENTS

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: U.S. Army Material System Analysis Activity

OBJECTIVE: To review the education and training requirements stemming from JTCG products and recommend a suggest a strategy for improvement.

SUMMARY: The JTCG/ME produces many operational products for all military services. At present training and education relating to these products is uncoordinated and sparse. The white paper will review existing training and educational programs relating to these products, identify potential shortcomings and recommend a strategy for improvement.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Software, Education and Training, Weaponeering

INTERFACIAL SLIDING IN MULTI-COMPONENT SYSTEMS

Indranath Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation

OBJECTIVE: To investigate the mechanisms of creep at interfaces of dissimilar materials.

SUMMARY: The goal of this project is to develop a phenomenological understanding of the mechanisms operative during sliding of interfaces at high temperatures. A combination of experimental and analytical means are being utilized to investigate the kinetics of interfacial sliding and its effect on thin film systems.

PUBLICATIONS:

Dutta, I., Chen, M.W., Peterson, K. and Shultz, T., "Plastic Deformation and Interfacial Sliding in Al and Cu Thin Film: Si Substrate Systems Due to Thermal Cycling," *Journal of Electronic Packaging*, Vol. 30, pp. 1537-1548, 2001.

Nagarajan, R. and Dutta, I., "A Novel Approach for Optimizing the Fracture Toughness of Precipitation-Hardenable Al-SiCp Composites," *Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science*, Vol. 32, pp. 433-436, 2001.

Dutta, I., Peterson, K. and Chen, M.W., "Plasticity and Interfacial Sliding in Cu Thin Film: Si Substrate Systems During Thermal Cycling," *Plasticity, Damage and Fracture at Macro, Micro and Nano Scales*, A.S. Khan and O. Lopez-Pamies, eds., *Proceedings Ninth International Symposium on Plasticity*, NEAT Press, pp. 117-119, 2002.

PRESENTATIONS:

Dutta, I., Chen, M.W., Peterson, K. and Shultz, T., "Interfacial Sliding at Thin Film: Semiconductor Substrate During Thermal Cycling," presented at the 130th Annual Meeting of the Minerals, Metals and Materials Society of AIME, New Orleans, LA, 11-15 February 2001.

THESES DIRECTED:

Shultz, T., "A Hot-Stage Atomic Force Microscope for Measuring Plastic Deformation in Thin Films on Silicon During Thermal Cycling," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Composite, Multi-layers, Thin Films, Creep, Interfacial Sliding

THERMO-MECHANICAL BEHAVIOR OF SOLDER JOINTS FOR ELECTRONIC PACKAGING

Indranath Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To obtain a mechanistic understanding of the relationship between microstructural coarsening and applied constraints during thermo-mechanical cycling of solder joints.

SUMMARY: Flip Chip and Ball Grid Array solder joints in electronic packaging applications are subjected to large imposed strains and temperature variations during service conditions. During cycling, the microstructure coarsens, plastic strains localize, and the solder joint eventually fails by low-cycle fatigue induced by permanent creep deformation. The purpose of this project is to understand the dependence of micrsotructural coarsening on the plastic strain state in a solder joint during thermo-mechanical cycling.

PUBLICATIONS:

Dutta, I., Gopinath, A. and Marshall, C., "Underfill Constraint effects during Thermo-Mechanical Cycling of Flip Chip Solder Joints," *Journal of Electronic Packaging*, in press (accepted November 2001, to appear in April 2002).

Dutta, I., "A Constitutive Model for Creep of Lead-Free Solders Undergoing In-situ Microstructural Coarsening: A First Report," *Journal of Electronic Packaging*, in review.

THESES DIRECTED:

Marshall, C., "Effect of Underfill Constraint during Thermo-Mechanical Cycling of Flip Chip Solder Joints under Shear," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Electronic Packaging, Solder, Thermal Cycling, Deformation

COMPOSITIONAL AND MICROSTRUCTURAL ANALYSIS OF ADVANCED ULTRA-LOW CARBON WELDMENTS

Alan G. Fox, Professor
Department of Mechanical Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: The objective of this work (which commenced in FY99) is to quantatively advance the ability to understand, predict and control microstructural evolution and mechanical behavior in advanced, low carbon steel weldments produced with new ultra-low carbon (ULC) filler metals. In particular, the goal is to elucidate the effects of weld chemistry and weld thermal processing history on compositional, microstrutural and mechanical properties variations across weldments and amongst different weldments and to use the experimental results both as input to, and as a direct quantative test of detailed weld simulation models developed at NRL.

SUMMARY: The work at NPS will involve the use of high resolution analytical transmission electron microscopy to determine the microstructure and microchemistry as a function of position within different ULC weldments particularly with respect to carbon in the weld metal and oxygen in the non-metallic inclusions generated as a result of the welding process.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: HSLA Steels, Welding, Ultra-Low Carbon Steel Weld, Electron Microscopy

THERMOFLUID AND THERMOMECHANICAL ISSUES IN ELECTRONIC PACKAGING

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To investigate the thermofluid and thermomechanical aspects of the electronic packaging of flip chips from a reliability viewpoint.

SUMMARY: This project was a continuation of the collaboration initiated in CY-2000 with Professor I. Dutta (also of the Department of Mechanical Engineering). Different topical areas were covered as follows:

(a) The flow characteristics of a liquid epoxy encapsulant designed as an underfill for flip chip devices was experimentally studied in a controlled manner. The area coverage by the underfill in capillary flow was measured as a function of chip bump pattern, point of application of underfill, and environment temperature. Observations of flow front uniformity and void formation were recorded which provide useful fundamental insight into the fluid filling challenges posed by continually reducing chip size.

(b) The effect of cycling of a localized heat source on the underside of a flip chip package die was studied in order to explore the possible formation of hot spots in the package resulting from heat flow inhibiting interfacial defects due to imperfect thermal contacts at key locations. An energy partitioning model was used to evaluate the reliability of the solder joints under such accelerated thermal fatigue cycling loads. The effects of different peak heat flux values, and thermal boundary conditions were investigated. The thermal results clearly show pronounced temperature gradients that can be induced within the package. The associated structural results applied to the damage model show that creep continues to be the primary mechanism of failure in the package.

(c) The role of underfill constraint in thermomechanical cycling was investigated in a controlled single joint shear experimental study to determine the extent of load transfer from the solder to the encapsulant. A finite element model was used to corroborate the essential deformation characteristics of the joint, and to provide insight into the experiments. The strain response of the solder joint was found to be significantly influenced by microstructural coarsening, which is countered by the hydrostatic stresses imposed by the underfill on the joint.

PUBLICATIONS:

Dutta, I., Gopinath, A. and Marshall, C., "Underfill Constraint Effects during Thermo-Mechanical Cycling of Flip Chip Solder Joints," due to appear in the *Journal of Electronic Materials*.

Dunne, J.E., Smith, V.E., Gopinath, A. and Dutta, I., "Modeling the Effects of Cycling of a Localized Heat Source on a FCOC with Defects," to be presented at the 52nd ECTC.

THESES DIRECTED:

Wennersten, S.M., "Flow Characteristics of Liquid Epoxy Underfill in a Narrow Gap for Flip Chip Devices," Masters Thesis, Naval Postgraduate School, March 2001.

Smith, V.E., "A Finite Element Analysis of Thermal Fatigue Stresses in the Solder Joints of a Flip Chip Package," Masters Thesis, Naval Postgraduate School, September 2001.

Dunne, J.E., "Modeling the Effect of Cycling of a Localized Heat Source in the Die of a Flip Chip Package with Defects," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Other (Electronic Packaging)

KEYWORDS: Flip Chip, Electronic Packaging, Thermomechanical Fatigue, Underfill, Capillary Flow

TURBINE CONVECTIVE COOLING CONCEPTS EVALUATION

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Air Warfare Center – Aircraft Division and
Defense Advanced Research Projects Agency

OBJECTIVE: To provide support and validatory analyses of ongoing work in a new MEMs-based micro-heat exchanger turbine cooling concept.

SUMMARY: This project is a new start in FY-2001. The primary thrust of the project was to develop a multi-physics computational analysis of the proposed heat exchanger design. The micro-heat exchanger is based on the concept of the use of pin fins in the narrow gap of a shroud enclosed turbine blade. A finite element numerical analysis based on the package ANSYS has been initiated to predict the flow and heat transfer characteristics of such a micro pin fin heat exchanger. In such a short pin fin enclosed array configuration, both the pins and the end wall make substantial contributions to the heat transfer which need to be identified. For the small pin fin size relative to the blade radius of curvature, a planar model was assumed and a fully three dimensional numerical analysis was carried out. Various streamwise and spanwise pin fin spacings were used to determine both row-averaged and array-averaged heat transfer coefficients for the heat exchanger. A range of flow Reynolds numbers was covered and the results corroborated with available data in the literature. The heat transfer performance was compared with overall pressure drop characteristics to predict an optimal configuration.

PUBLICATIONS:

Adametz, D.S., Hamilton, L.J. and Gopinath, A., "Numerical Analysis of the Performance of a Staggered Cross-Pin Array Heat Exchanger," to be presented at the 8th AIAA/ASME Joint Conference.

THESES DIRECTED:

Adametz, D.S., "Numerical Analysis of Heat Exchanger Performance for a Staggered Short Pin-Fin Array," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power

KEYWORDS: Pin-Fin Array, Compact Heat Exchanger, Micro Heat Exchanger, Turbine Blade Cooling

EVALUATION OF COOLING TECHNOLOGIES FOR MAGNETORESTRICTIVE ACTUATORS

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center – Carderock Division

OBJECTIVE: To evaluate available cooling technologies that would work within the design constraints of magnetorestrictive actuators and maintain operating temperatures below a safe threshold.

SUMMARY: This project was a short term piece of work for NSWC carried out in CY-2001. The goal of the project was to investigate and recommend possible cooling technologies that would maintain the temperature of magnetorestrictive actuators under safe operating limits. After exploring various options, and keeping the design constraints in mind, it was recommended that for baseline use simple low maintenance off the shelf heat exchanger components with no moving parts be used for robust and reliable performance of the actuator in the harsh environments envisioned. It was found that the basic cooling needs could be met with an extended surface natural convection cooling design such as a press fitted pin fin assembly. The working constraints were that the ambient temperature could be a high as 35°C while the actuator temperature was not to exceed 95°C, and that the final package was to fit within a cylindrical package of dimensions no more than one foot in length and diameter. Sample baseline calculations were provided for a typical case of an assembly of 35 circular/annular aluminum fins that could provide a heat transfer rate of as much as 650°W. In addition, active cooling enhancement strategies were recommended through the use of vortex tubes that work off standard high pressure air lines to provide a jet/stream/curtain of cold air. It was suggested that strategically located vortex tubes could be used to provide an empirically calibrated blast(s) of cold air on the actuator along the length of its travel to maintain its temperature within safe operating limits.

PUBLICATIONS:

Gopinath, A., "Evaluation of Cooling Technologies for Magnetorestrictive Actuators," Technical Report.

DoD KEY TECHNOLOGY AREA: Other (Cooling Technologies)

KEYWORDS: Magnetorestrictive Actuator, Natural Convection, Fin Assembly, Vortex Tubes

EFFICIENT NONLINEAR TRANSIENT DYNAMIC ANALYSIS FOR STRUCTURAL OPTIMIZATION USING AN EXACT INTEGRAL EQUATION FORMULATION

Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Beny Neta, Professor
Department of Applied Mathematics
Sponsor: National Science Foundation

OBJECTIVE: This project is concerned with the theoretical development and computational implementation of a time domain theory for locally nonlinear transient structural synthesis. Application principally will be made to seismic isolation.

SUMMARY: This research concerns the continued development of a time domain theory for structural synthesis. This theory provides the previously unavailable capability of performing exact damped transient structural synthesis for systems with localized nonlinear components with the order of the synthesis being independent of model size. The method is based on Volterra integral equations derived from the convolution integral which describe substructure coupling and structural modification. Current results demonstrate an order of magnitude reduction in compute times as compared with widely-used commercial finite element analysis packages. The use of the formulation for the optimal design of seismic isolation is under development. The algorithm has been extended to treat nonlinear memory-type elements (e.g. elastoplastic hysteretic).

PUBLICATIONS:

Gordis, J.H. and Neta, B.,"Fast Transient Analysis for Locally Nonlinear Structures by Recursive Block Convolution," *ASME Journal of Vibration and Acoustics*, Vol. 123, No. 4. pp. 545-547, 2001.

THESIS DIRECTED:

Jarque, A.V., "Recursive Block-by-Block Integral Equation Solution for Transient Dynamic Analysis with Memory Type Elements," Masters Thesis, Naval Postgraduate School, March 2001.

Norton, K.M., "Parameter Optimization of Seismic Isolator Models Using Recursive Block-by-Block Nonlinear Transient Structural Synthesis," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Structural Dynamics, Transient Response, Nonlinear Dynamics, Seismic Isolation

DESIGN OF LAB-SCALE MODEL TEST OF ISOLATION FOR ROLL-ON ROLL-OFF (RORO) RAMP

Joshua H. Gordis, Associate Professor
Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: The objective of this project was to perform frequency response analysis of the DTMB runs 1-503 and NRL runs 1-217 of the T-ACS seakeeping experiments.

SUMMARY: In Sea State 3 and above, the stern ramp of the Cape T ship is vulnerable to an overstress condition when off-loading vehicles. Therefore, there exists a need to design motion-compensation devices ("isolation") which when placed between the end of the ramp and the barge, precludes the possibility of a ramp overstress condition. Parallel to analytical studies conducted under separate funding, there is a need to establish an accurate and cost-efficient experimental set-up in order to validate the theoretical models. This need is addressed in this work. A basic experimental configuration has been designed and built. Actual testing and data analysis is set to begin during the month of February. Further data analysis and conclusions along with recommendations of the most promising designs will be reported during this year.

THESES DIRECTED:

Trevisan, R.A., "Development of Experimental Facility for Roll-On Roll-Off Ramp Isolation Dynamics," Master Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, Vibration Isolation, Testing and Evaluation

MOTION MINIMIZATION IN HIGH SPEED TOWING OPERATIONS

Joshua H. Gordis, Associate Professor
Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Funding: Office of Naval Research

OBJECTIVE: The objective of this project was to support the Office of Naval Research in further development of the novel SLICE hull form with a trailer hull.

SUMMARY: The focus of this project was on a hinge connection between the "tractor" and "trailer" SLICE vessels. This provides a number of technical challenges in high-speed high sea state ocean towing systems that have not been studied in the past. A model describing the dynamics of the two bodies under tow was developed. A series of runs was conducted in order to gain some insight into the seakeeping behaviors of the two ships. A generic spring/damper connection was assumed to exist at the interface. Current studies aim at more realistic configurations, along with the establishment of a design and analysis procedure in order to quantify the performance degradation in a seaway. A simulation model for low frequency motions was also developed, and a comprehensive stability analysis is underway.

THESES DIRECTED:

Nash, C., "Vertical Plane Response of Surface Ships in Close Proximity Towing," Masters Thesis, Naval Postgraduate School, June 2001.

Jones, G.D., "Semi-Rigid Maneuvering Model for Analysis of Maneuvering in the Horizontal Plane," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Towing, Seakeeping

REDUCING RAMP STRESS LEVELS VIA SEMI-ACTIVE DAMPING

Joshua H. Gordis, Associate Professor
Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center - Carderock Division

OBJECTIVE: The current ramp design used in roll-on roll-off (RORO) operations has been determined to be structurally inadequate in sea state 3. The overall objective of this continuing project is to determine the isolation properties that are required in order to reduce ramp stress levels below the allowable for worst-case loading.

SUMMARY: A mathematical model describing the fundamental physics of a ship/ramp/barge system, including a passive isolator, was developed. The model properly accounts for hydrodynamic proximity effects and structural coupling between the bodies. Preliminary parametric studies, utilizing a standard second order model for the frequency response properties of the connecting body, of the response amplitude operator of the ramp motion were performed for varying wave directions and isolator stiffness and damping. These were utilized for random wave analysis in standard fully developed seas. The results indicated that rational selection of isolator properties could result in significant reduction of motions and stress levels in the connecting ramp. Current efforts include incorporation of actual FEM results coupled with the existing hydrodynamic prediction models.

THESES DIRECTED:

Buckley, J.E., "Computational Mechanics of the Full-Scale and Model-Scale Roll-On, Roll-Off (RORO) Stern Ramp and Experimental Modal Analysis of the Model-Scale Ramp and Support," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, RORO Operations, Vibration Isolation

STUDIES IN INTELLIGENT CONTROL OF AUTONOMOUS VEHICLES

Anthony J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Ford Motor Company

OBJECTIVE: This grant is in the support of research in the subject matter and serves to aid the ongoing programs in the Center for Autonomous Underwater Vehicle Research.

SUMMARY: This project has supported the purchase of radio ethernet communications devices and radio modem connections between the *ARIES* robot and a shore based operator station. Also, it has supported the purchase of mobile laboratory equipment necessary to the deployment of *ARIES* in Monterey Bay.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles, Ships and Watercraft

KEYWORDS: Autonomous Systems, Robotics, Vehicles, Navigation

HYDRO-THERMAL VENT MAPPING WITH MULTIPLE AUTONOMOUS UNDERWATER VEHICLES (AUV)

Anthony J. Healey, Professor
Department of Mechanical Engineering
D. B. Marco
Center for Autonomous Underwater Vehicle Research
A. Pascoal
University of Lisbon, Lisbon, Portugal
Sponsor: Office of Naval Research

OBJECTIVE: The IST has been conducting missions in the Azores using a surface catamaran vehicle (*DELFIM*) with plans to add an underwater vehicle (M*ARIUS*). NPS will provide the cooperating underwater vehicle *ARIES* which has a video capability and an acoustic modem for underwater communications.

The approach for mapping these shallow water vent areas will be to employ an echo sounder on the *DELFIM* to provide bathymetry and detect the presence and general location of clusters of vents. *DELFIM* will communicate the cluster location data information by acoustic and radio modems to the NPS *ARIES* AUV. The *ARIES* will have the capability to reacquire the vent area using its DGPS / Doppler / IMU navigational suite, and to conduct a survey of the local area with a video camera. *ARIES* will provide geo-located video images of the vents, taken from a slow speed local search at constant altitude.
A joint exercise was conducted with IST, NPS, and the University of the Azores during the month of August near the Island of Faial, Azores. The detail objectives were:

- Demonstrate two vehicle underwater communications.
- Obtain video confirmation of shallow water hydro-thermal vent activity using video with location obtained from an independent source.

SUMMARY:

- Navigational accuracy mostly errors < 5m obtained with GPS popup.
- Video acquisition obtained of vent area given position from an independent source. Vent bubbles were found.
- Acoustic communications between *DELFIM* and *ARIES* with FAU modem where each vehicle was operated under autonomous control.
- All commands were received successfully and acted upon with no retransmits. The commands were sent from the support ship to the *DELFIM* and then to *ARIES*. Ranges up to 700m with 2 vehicles underway.

For this mission, a pair of acoustic modems were installed on the *ARIES* and on the IST *DEFIM* autonomous surface craft. Two laptop computers were used on the research vessel *ARQUIPELAGO* and are referred to as the base station systems. One laptop is used for command and control directly to the *ARIES* controlling computer through a radio link while the vehicle is surfaced. The second laptop is a two part link using both radio and acoustic modem communications. Radio communications are used from the *ARQUIPELAGO* surface ship to the *DELFIM*, at which point the data is sent to an acoustic modem mounted below the craft and allows communications with the *ARIES* while it is submerged.

The current configuration of the acoustic modem allows sending character strings up to 256 characters in length per transmit. For reasons of future compatibility across different systems, NMEA style ASCII strings are used as a standard format for the messages defined. The general form of all messages sent or received from the modem are of the form:

PUBLICATION:

Healey, A.J., Marco, D.B. and Pascoal, A.M., *Hydro-Thermal Vent Mapping with Multiple AUVs: AZORES-2001*, Naval Postgraduate School Technical Report, NPS-ME-01-007.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles, Ships and Watercraft

KEYWORDS: Autonomous Underwater Vehicles, AUV, Hydro-thermal Vent Mapping

TACTICAL DECISION AIDS USING MODELING AND SIMULATION

Anthony J. Healey, Professor
Department of Mechanical Engineering
Jane Wu, Contractor
Don P. Brutzman, Associate Professor
Department of Information Science
Sponsor: Office of Naval Research

OBJECTIVE: The goals are to develop Tactical Decision Aids for using small autonomous underwater vehicles (AUVs) in very shallow water (VSW) environments. TDAs enable operators to view data gathered by these vehicles and make informed decisions as to the conduct of mine countermeasures operations.
The current tactical decision aids system used by the U.S. Navy for mine countermeasures is a system named MEDAL (Mine Warfare Environmental Decision Aids Library). MEDAL is a software package running inside the GCCS-M global command and control system used by Navy ships. It is used to evaluate asset positions, minelike contacts, snippet images of contacts, snippet images of those contacts later identified as mines, and bathymetry maps. Other data such as bottom typing may be displayed if available. The objectives include the timely gathering of AUV data, converting, archiving, and translating it into the form familiar in MEDAL to Naval operational personnel. The goal is to improve the timeliness of data gathering including the post processing of sonar and video images for import into MEDAL. Long term goals are to integrate 3D visualization of data to enhance decision making, particularly in regard to deciding whether a contact is in fact a mine.

One issue in this project is how to deal with data from unclassified assets that are in development from university institutions, translate into the form used by MEDAL, and import the results into the classified Navy systems used in the fleet. To this end we have defined an automated data server system (ADS) that is linked through a local area network (LAN) to a stand alone MEDAL system. The MEDAL system runs on a TAC4 or better HP workstation. At the present time, it only runs on the HP systems with the 10.20 OS and the GCCS-M operating system. The ADS has been refined and is now interactive through screen entry from an operator. Future versions will be automated without operator intervention so that the software could run inside the control system of the AUVs. The ADS allows the operator to view data through a VRML 3D viewer in which models of vehicles and contacts can be seen thereby extending MEDAL into 3-D views.

SUMMARY: The initial version of the ADS has been developed and demonstrated during both Fleet Battle Exercise Hotel and its rehearsal. This initial version uses operator intervention to gather and translate AUV data into MEDAL format. During the demonstrations, data gathered from the *REMUS* (SHARV), *Morpheous*, and *Drake* vehicles included track positions, bathymetry (water column depth) at each track point, and, after sonar and video data processing, the image files (jpeg / gif) for contacts and their locations. The data were converted into MTF message formats and imported into MEDAL. MEDAL data was available for the fleet operators to view and plan tasking for the vehicles.
Work conducted in FY 2001 included:

- purchase of a fast HP workstation to better allow display of bathymetry data files
- preparation and on site data gathering and display support for the Kernal Blitz 01 exercise in March at Camp Pendleton
- conducting a test with the NPS *ARIES* AUV with an aerial relay link to transmit data files from the surfaced vehicle to the command center.

An HP C3600 workstation was purchased and a version of MEDAL Build 7 was set-up running in an external drive. The data bases have been transferred in part from last years exercise - FBE-Hotel. In the new configuration, the data flow from the NPS ADS software is through a LAN coonnection, but there is still no direct connectivity between the post-processing workstations for the AUVs and the ADS. We developed a LAN connection with the *REMUS* console, but other vehicles such as the *BPAUV* were operated off shore and had no ability to transmit data back to the command and control center.

In addition to data gathering, and during the KB01 exercise held at Camp Pendleton March 2001, a series of experiments was run with the *ARIES* underwater vehicle (http://www.cs.nps.navy.mil/research/auv/auvframes.html), it's support boat, (a Boston whaler), the *PELICAN* aircraft, and the control station at the ONR base. The objective was to transfer an image file pre-stored on the *ARIES* AUV, through

the aircraft to the ONR base while the aircraft was flying an AROSS sensor mission and investigate transmit rate for distances over several kilometers.

The *ARIES* was towed to site on "White Beach" and from 1:00pm March 17, til 3:00 March 17, 2001, Regular communication links were obtained between the ARIES on board computers and the ONR base station set up on the Camp Pendleton BOQ.

PUBLICATION:

Healey, A.J., Wu, J. and Brutzman, D.B., "Tactical Decision Aids Using Modeling and Simulation," Ocean Engineering and Marine Systems Report 2000, ONR 32100-1, pp. 221-224, December 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Undersurface Vehicles - Ships and Watercraft

KEYWORDS: Underwater Robotics, Mine Countermeasures, Modeling and Simulation, Graphics, Physics Based Models

MODELING OF FIRE AND SMOKE PROPAGATION IN SHIPBOARD SPACES

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: The overall objective of this work is to investigate the effects of survivability considerations on the design of ships. Specifically work has been continuing to investigate the modeling of smoke propagation in shipboard compartments and passageways. It is very important that an understanding of the propagation of fire and smoke in the various shipboard spaces be developed and that some means be developed to apply that understanding to incorporate survivability considerations in the design of future combatants and to the development of fire fighting procedures.

SUMMARY: The propagation of fire-generated smoke with a counter-flow air supply in a horizontal arrangement of shipboard compartments and passageways was modeled using a computational fluid dynamics program generated by Computational Fluid Dynamics Research Corporation. This study was based on a large-scale live fire experiment performed by Naval Research Laboratory on the ex-*USS SHADWELL*. All simulations were evaluated at steady state conditions. A constant velocity counter-flow air supply was introduced into the model structure. The counter-flow air velocities used were 0.5, 1, and 2 m/s. This study used a Computational Fluid Dynamics combustion module to simulate a 620 kW fire generated by the complete combustion of propene gas from a burn pan in the space. Carbon dioxide from the fire was tracked throughout the structure to model smoke propagation. Seven simulations were performed with adiabatic and isothermal bulkhead, deck and overhead boundary conditions. Simulation smoke propagation results were consistent with experimental observations. Figures depicting temperature distribution, carbon dioxide distribution and mixture flow patterns at specified locations are provided in the report. The goal of this study is to evaluate the effectiveness of computational fluid dynamics modeling of smoke propagation in a shipboard space with a counter-flow air supply.

THESES DIRECTED:

Farman, G.J., “Modeling of Shipboard Smoke Propagation with a Forced Counter-Flow Air Supply,” Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Fire Propagation, Smoke Spread, Ship Survivability, Damage Control

INVESTIGATION OF THE USE OF ARTIFICIAL NEURAL NETWORKS IN HEAT TRANSFER

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The objective of this study is to investigate the feasibility of employing the neural network technique as a method of using experimental data to predict heat transfer behavior. Currently, data is acquired by experimentation, collected, and then correlated to one or more of the controllable inputs using some physical and mathematical insight. Experimental uncertainties in the data accumulation are coupled with the inherent uncertainties in the mathematical correlation

It is the goal to use neural networks, to make the predictions of thermal fluid behavior more reliable, less reliant on assumptions, and provide easier methods of evaluating these predictions. With neural networks all of the above goals are possible.

SUMMARY: Artificial neural networks have been employed to develop a predictive algorithm using experimental heat transfer data for a complex situation. The from a series of experiments investigating the boiling heat transfer from a vertical bank of tubes in refrigerant 114 with variable amounts of oil present has been used to illustrate the process. Both finned and unfinned tubes were investigated. The network was trained with a partial set of the available data. The prediction obtained using the trained network was then compared to the remaining experimental data. The artificial neural network provided an excellent predictive method.

PUBLICATIONS:

Kelleher, M.D., Gronley, T.J., Yang, K.T. and Sen, M., "Using Artificial Neural Networks to Develop a Predictive Method from Complex Experimental Heat Transfer Data," *Proceedings of the International Mechanical Engineering Congress*, New York, NY, November 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Artificial Neural Networks

MODELING AND SIMULATION OF DAMAGE AND CRACKS IN PARTICULATE COMPOSITE MATERIALS: EFFECTS OF PRESSURE LOADING

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsors: Air Force Research Laboratory and Naval Postgraduate School

OBJECTIVE: This was a continuing research project from past several years during which a numerical modeling and simulation technique, called a multi-level (micro-macro) technique, had been developed and evaluated against experimental results. This year's effort was to study the effect of pressure loading on damage initiation and growth and to model the effect in the damage mechanics.

SUMMARY: The stress-strain behavior of a particulate composite specimen under hydrostatic pressure was modeled using the multi-scale approach. The approach was developed in the past by the investigator. The damage was described at the micro-level analysis in terms of the respective damage of each constituent material. In the present study, a damage theory was developed based on the two components of strain energy density: dilatational and deviatoric energy densities. The dilatational energy associated with the hydrostatic pressure was assumed to hold back the damage initiation. As a result, a damage theory including the hydrostatic pressure effect was developed and tested against experimental data of a specimen with the star-shaped opening. The stress-strain curves predicted from the theory agreed well with the experimental curves.

The initial crack sizes at notch tips were predicted and compared to the experimental results with or without initial hydrostatic pressure. The predicted values compared very well to the test data. The crack

formation occurred either at the root of the large semi-circular notch or at the root of the smaller radius section which connected the large semi-circular section and the straight section. The two locations competed each other. The sizes and locations of initial cracks were in good agreement between the experimental and numerical results.

PUBLICATIONS:

Kwon, Y.W. and Craugh, L.E., "Progressive Failure Modeling in Notched Cross-Ply Fibrous Composites," *Applied Composite Materials*, Vol. 8, No. 1, pp. 63-74, January 2001.

Kwon, Y.W. and Liu, C.T., "Effect of Particle Distribution on Initial Cracks Forming from Notch Tips of Composites with Hard Particles Embedded in a Soft Matrix," *Composites, Part B: Engineering*, Vol. 32, pp. 199-208, 2001.

Kwon, Y.W., "Multi-level Approach for Failure in Woven Fabric Composites," *Advanced Engineering Materials*, Vol. 3, No. 9, pp. 713-717, 2001. (Invited Paper)

Kwon, Y.W. and Altekin, A., "Multi-level, Micro-Macro Approach for Analysis of Woven Fabric Composites," *Journal of Composite Materials*, accepted for publication.

Kwon, Y.W. and Lannamann, D.L., "Dynamic Modeling and Simulation of Interfacial Cracks in Sandwich Structures for Damage Detection," *Journal of Sandwich Structures and Materials*, accepted for publication.

Kwon, Y.W., "Multi-Scale, Multi-Level, Micro/Macro-Approach for Progressive Damage in Composite Structures," A Europe/USA Initiative on: The Structural Integrity of Composite Materials and Structures, Isle of Capri, Italy, May 2001. (Invited paper)

Kwon, Y.W. and Eren, H., "Boundary Element Analysis of Fiber/Matrix Interface," International Conference on Computational Engineering and Sciences, Puerto Vallarta, Mexico, August 2001.

Kwon, Y.W. and Liu, C.T., "Effect of Hydrostatic Pressure on Damage in Particulate Composites," Recent Advances in Solids and Structures -2001, IMECE 2001, CD-ROM Vol. 3, PVP-25201, 2001.

THESIS DIRECTED:

Altekin, A., "Multi-level Technique for Stiffness and Strength Calculations of Woven Fabric Composite Plate and Shell Structures," Masters Thesis, Naval Postgraduate School, June 2001.

Lannamann, D.L., "Structural Health Monitoring: Numerical Damage Predictor for Composite Structure," Masters Thesis, Naval Postgraduate School, March 2001.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power, Materials, Processes, and Structures, Modeling and Simulation

KEYWORDS: Particle Reinforced Composite, Solid Rocket Propellant, Damage and Crack, Modeling and Simulation, Initial Crack Size, Hydrostatic Pressure

MODELING AND SIMULATION OF THE HUMAN THORAX UNDER BULLET IMPACT

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsor: Armed Forces Institute of Pathology

OBJECTIVE: This was a continuing research project from the previous years. This year's effort was to model the human thorax especially including major internal organs with protective body armors hit by high-speed bullets in order to evaluate potential injury.

SUMMARY: The finite element analysis model was developed for the human thorax of skeleton with internal organs. The skeleton includes ribs, sternum, vertebrae, vertebral discs, facet joints, costal cartilages, muscle, etc. while internal organs include the lung, heart, trachea, etc. Two different body armors, one with a Kevlar vest and the other with a vest and armor plate, were also modeled. The results of the computer model were compared to the experimental data obtained with human cadavers with body armors hit by bullets. In the model, the measured speed of the bullet was used. The comparison of accelerations in the sternums, spines, lung, and heart were very good. The pressure inside the heart compared well between the experimental and numerical results. Those results provided reliability of the developed computer model. The program was extended to include the head and neck injury including brain damage.

PUBLICATION:

Kwon, Y.W. and Lobouno, J.A., "Biodynamics of Human Thorax with Body Armors Subject to Ballistic Impact," Recent Advances in Solids and Structures -2001, IMECE 2001, CD-ROM Vol. 3, PVP-25206, 2001.

Lobuono, J.A. and Kwon, Y.W., *Biodynamical Response of the Human Thorax to a Projectile Impact*, Naval Postgraduate School Technical Report, NPS-ME-01-001, March 2001.

THESIS DIRECTED:

Lobuono, J.A., "Biodynamical Response of the Human Thorax to a Projectile Impact," Masters Thesis, Naval Postgraduate School, March 2001.

George, D.N., "Finite Element Modeling of the Human Head and Neck for Injury," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Finite Element Method, Human Thorax Model, Body Armors, Dynamic Response

UNIT-CELL MODEL OF OPEN METALLIC FOAM

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: This project was to develop a unit-cell model to compute the effective strength and stiffness of an open-cell metallic foam structure.

SUMMARY: Representative unit-cell models were developed for open cell metallic foams in order to predict their effective elastic moduli and the plastic collapse strengths. Two different open-cell metallic foams were considered. One was just open cell foam and the other was open cell foam filled with an elastic material. The models were based on the metallic frames consisting of edges of tetrakaidecahedron. The filling material was modeled as elastic foundation to the ligament frames. The frame structure of the unit-

cell was analyzed using the finite element method. The plastic collapse strength was determined when the joints of ligaments became plastic hinges under the assumption of elastic-perfectly plastic material behavior of the metallic material. Both elastic modulus and plastic collapse strength were computed using a single step of finite element analysis without any iterative or incremental procedure. In addition, a very small number of finite elements was used. As a result, the unit-cell is computationally very efficient. In order to assess the representative unit-cell models, experiments were also conducted. The experimental data agreed very well with the predicted values of both stiffness and strength.

PUBLICATION:

Kwon, Y.W. and Cooke, R.E., "Representative Unit-Cell Model for Open-Cell Metal Foam," submitted to *Materials Science and Engineering A*, 2001.

THESES DIRECTED:

Cooke, R.E., "Finite Element Modeling of Metal Foam Structures Subject to Compressive Loading," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Metal Foam, Open-Cell, Unit-Cell Model, Effective Stiffness and Strength

MECHANICAL AND MICROSTRUCTURAL CHARACTERIZATION OF COMMERCIAL AA5083 MATERIALS

Terry R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: University of Texas - Austin and GM Research and Development Center

OBJECTIVE: The goals of this program are: to characterize the fundamental deformation mechanisms in grain-refined AA5083 aluminum alloy material during elevated temperature deformation; and to characterize the failure mechanisms in materials from various sources.

SUMMARY: Our current understanding of microstructural refinement by deformation and recyrstallization is largely empirical and so the ability to predict and then produce refined microstructures for various purposes, such as superplasicity, is limited. Recently developed computer-aided electron backscatter diffraction analysis and orientation imaging microscopy (OIM) methods have been applied to the investigation of the mechanisms of grain refinement and grain boundary development during processing of AA5083. Materials have been examined following various thermomechanical treatments and deformation histories. Grain refinement occurs via particle stimulated nucleation of primary (discontinous) recrystallization resulting equiaxed grains, a nearly random texture, and random disorientation distribution. During elevated temperature deformation dislocation creep is indicated by the formation of a <111> fiber texture while grain boundary sliding is marked randomizing of the initial texture. Thus, local deformation conditions can be monitored by texture analysis. Cavity formation can also be evaluated by OIM.

PUBLICATIONS:

Pérez-Prado, M.T., McNelley, T.R., González-Doncel, G. and Ruano, O.A., "Texture, Grain Boundaries and Deformation of Superplastic Aluminum Alloys," in *Proceedings of ICSAM 2000*, International Conference on Superplasticity in Advanced Materials, (N. Chandra, ed.), Materials Science Forum, Trans Tech, Zurich, pp. 255-260, 2001.

Eddahbi, M., McNelley, T.R. and Ruano, O.A., "The Evolution of Grain Boundary Character during Superplastic Deformation of an Al-6%Cu-0.4%Zr Alloy," *Metallurgical and Materials Transactions A*, Vol. 32A, pp.1093-1102, 2001.

Pérez-Prado, M.T., Swisher, D.L. and McNelley, T.R., "Deformation Banding, Grain Boundaries and Continuous Recrystallization in a Superplastic Aluminum Alloy," in *Proceedings of THERMEC 2000*, International Conference on Processing and Manufacturing of Advanced Materials (T. Chandra, ed.) Elsevier, London, Section G2, 2001.

Pérez-Prado, M.T., González-Doncel, G., Ruano, O.A. and T.R. McNelley, "Texture Analysis of the Transition from Slip to Grain Boundary Sliding in a Discontinuously Recrystallized Superplastic Aluminum Alloy," *Acta Materialia*, Vol. 49, pp. 2259-68, 2001.

PRESENTATIONS:

McNelley, T.R., Harrell, J.W. and Taleff, E.M., "Application of Orientation Imaging Microscopy Methods to Superplastic Aluminum Alloys," presented in the International Symposium on Superplasticity and Superplastic Forming, Annual Fall Meeting of ASMI, Indianapolis, IN, 7 November 2001.

McNelley, T.R., "Deformation Mechanisms and Ductilities of AA5083 Materials II: Orientation Imaging Microscopy," invited seminar, General Motors Research and Development Center, Warren, MI, 24 August 2001.

THESIS DIRECTED:

Harrell, J.W., "Analysis of the Transition in Deformation Mechanisms in Superplastic 5083 Aluminum Alloys by Orientation Imaging Microscopy," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Aluminum, Superplasticity, Recrystallization, Grain Boundaries, Thermomechanical Processing

ULTRA-FINE AND NANO-GRAIN MICROSTRUCTURES BY SEVERE PLASTIC DEFORMATION

Terry R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The goal of this program is to determine mechanisms by which ultra-fine grain structures form in severely deformed materials, such as those processed by equi-channel angular (ECA) pressing.

SUMMARY: Ultra-fine grain sizes in the sub-micrometer or even nanometer range can be achieved in metallic materials by imposing extremely large plastic strains during deformation processing. Such grain refinement will result in drastic improvements in strength/toughness combinations for structural application,s as well as in improved ductility during elevated temperature forming. Methods such as ECA pressing are required in order to impart stains large enough to produce such refinement. ECA pressing is accomplished by pressing a billet of material through a die having two channels, of equal cross section, that intersect at an angle. Such a billet experiences simple shear without change in cross-sectional area and so the process is amenable to repetition. Billet rotation between successive pressing operations allows the shear plane orientation to be changed in order to achieve further control of microstructural refinement. The characteristics of the grain structures and, especially, the nature of the grain boundaries produced by such processing have remained in question. However, grain-to-grain misorientations may be readily determined by newly developed computer-aided electron backscatter pattern (EBSP) analysis methods.

PUBLICATIONS:

McNelley, T.R. and Swisher, D.L., "Deformation Banding and Grain Boundaries in Aluminum and Aluminum Alloys," in *Modeling the Performance of Engineering Structural Materials II* (D.R. Lesuer and T.S. Srivatsan, eds.) TMS, Warrendale, PA, pp. 195-202, 2001.

McNelley, T.R., Swisher, D.L. and Pérez-Prado, M.T., "Deformation Bands and the Formation of High-Angle Grain Boundaries in a Superplastic Aluminum Alloy," *Metallurgical and Materials Transactions*, in press.

Terhune, S.D., Swisher, D.L., Oh-ishi, K., Horita, Z., Langdon, T.G. and McNelley, T.R., "An Investigation of Microstructure and Grain Boundary Evolution during ECA Pressing of Pure Aluminum," *Metallurgical and Materials Transactions*, in press.

PRESENTATIONS:

McNelley, T.R., Swisher, D.L. and Pérez-Prado, M.T., "Deformation Bands and the Formation of High-Angle Grain Boundaries in a Superplastic Aluminum Alloy," La Jolla / DoE Workshop on Creep and Creep Fracture, San Diego, CA, 27 June 2001.

McNelley, T.R. and Swisher, D.L., "Deformation Banding and Grain Boundaries in FCC Metals and Alloys," Symposium on Modeling the Performance of Structural Materials, Annual Fall Meeting of TMS, Indianapolis, IN, 6 November 2001.

McNelley, T.R., "Orientation Imaging Microscopy: Deformation-Induced Microstructures and Superplasticity in Aluminum Alloys," invited seminar, Department of Materials Science and Engineering, Kyushu University, Fukuoka, Japan, 28 July 2001.

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Aluminum, Grain Refinement, Nano-Grain Materials, Recrystallization, Grain Boundaries, Materials Processing

LOW OBSERVABLE MULTI-FUCTION STACK (LMS) EXHAUST GAS SUPPRESSION AND SUPPORT OF AT-SEA TRIALS

Knox T. Millsaps, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Weapon Center – Carderock Division

OBJECTIVE: To develop and demonstrate a gas turbine exhaust signature suppression system, which is capable of meeting specified infrared (IR) and radar cross-section (RCS) goals, under specific engine-imposed constraints and overall systems constraints that the system be integrated into a low observable topside.

SUMMARY: This was the final year of a 4-year advanced technology demonstrator (ATD) project to develop a low observable multi-function stack (LMS) as part of the series of ATDs to create integrated topside technology for the next generation of surface combatants. In previous years, the NPS part of this project was to create design concepts and develop supporting analytical codes for the preliminary design of enhanced mixing eductors, and to test and optimize cold-flow geometry for reducing plume radiation. These designs were next tested at larger scale at a hot-flow facility in Memphis with NPS assistance. Finally, last year the full-scale hardware was tested in an at-sea trial. NPS supplied engineering consulting services as well as integration advice throughout the project and was a member of the integrated product team (IPT).

PUBLICATIONS:

Ratcliffe, R., Imber, R., Bird, W. and Millsaps, K.T., "Test Report for LMS at Sea Trials," Report number not yet assigned. SECRET.

Ratcliffe, R., Imber, R., Bird, W. and Millsaps, K.T., "Final Report for the Low Observable Multi-Function Stack Advanced Technology Demonstrator Program," Report number not yet assigned. SECRET.

THESIS DIRECTED:

Markowicz, J.C., "Validation of Low Observable Stack Eductor Design for Gas Turbine Exhaust Systems," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Other (Signature Control)

KEYWORDS: Propulsion, Signature, IR, Gas Turbines, Exhaust, Enhanced Mixing

REVIEW OF ADVANCED TECHNOLOGY GAS TURBINE RESEARCH AND DEVELOPMENT PROGRAMS

Knox T. Millsaps, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Systems Engineering Station

OBJECTIVE: To review and evaluate the current research and development program for the advanced technology gas turbine program for the U.S. Navy's surface fleet gas turbine life cycle manager and to make technical recommendations for program improvement.

SUMMARY: A review of the Condition Based Maintenance (CBM) program for gas turbines for both power and propulsion, which started in November of 2001, is in progress. The major area of interest is to develop a technology road map for interfacing component level engine CBM modules into the Navy's Integrated Condition Assessment System (ICAS). More specifically, a review of methods to determine degradation in compressor performance due to dirt and salt deposition is underway as is the modeling of sensor and performance measures.

DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation, Other (Reduced Manning)

KEYWORDS: Propulsion, Gas Turbines, Condition Based Maintenance (CBM), Compressor Fouling

WEB-BASED NAVAL ARCHITECTURE FOR PD-21

Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Funding: Center for Naval Education and Training

OBJECTIVE: The purpose of this project was to develop a web based class on Naval Architecture in support of the PD21 and the TSSE programs.

SUMMARY: The purpose of this project was to develop a web based class on Naval Architecture in support of the PD21 and the TSSE programs. The outcome of this project was the development of a comprehensive web site on Naval Architecture, with over two thousand files, incorporating text, graphs, support information material, and fully interactive examples. The site is fully integrated into the Blackboard web based delivery system adopted by NPS.

OTHER:

A fully functional web site, in essence an electronic textbook on Naval Architecture.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software, Manpower, Personnel and Training.

KEYWORDS: Naval Architecture, Web-based Instruction, Javascript

EXTENDED STATE SPACE MODELING OF RRDF INTERFACE

Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Funding: Naval Surface Warefare Center - Carderock Division

OBJECTIVE: The goal of this project was to develop a model in order to bridge the gap between existing constant coefficient time domain and more accurate hydrodynamic models.

SUMMARY: A mathematical model describing the fundamental dynamics in the interface problem between a ship, a barge, and a connecting ramp was developed and solved. The hydrodynamics for the ship and the barge were described by a 12-degree of freedom fully coupled model, which was based on potential theory and incorporated proximity effects. Ramp structural dynamics were studied by a finite element model, which was calibrated based on detailed studies of commercially available codes. The models were coupled together through a spring/damper and the solution of the system was obtained in both regular waves and a representative sea state. Parametric studies with regards to different coupling conditions proved that optimization based on either relative motions or ramp maximum stress is possible.

THESES DIRECTED:

Dalakos, A., "A Coupled Hydrodynamic/Structural Model for Ship/Barge/Ramp Interface," Masters Thesis, Naval Postgraduate School, December 2001.

Trevisan, R., "Development of Experimental Facility for Roll-On Roll-Off Ramp Isolation Dynamics," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, RORO Operations, Vibration Isolation

MOTION MINIMIZATION IN HIGH SPEED TOWING OPERATIONS

Fotis A. Papoulias, Associate Professor
Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Funding: Office of Naval Research

OBJECTIVE: The objective of this project was to support the Office of Naval Research in further development of the novel SLICE hull form with a trailer hull.

SUMMARY: The focus of this project was on a hinge connection between the "tractor" and "trailer" SLICE vessels. This provides a number of technical challenges in high-speed high sea state ocean towing systems that have not been studied in the past. A model describing the dynamics of the two bodies under tow was developed. A series of runs was conducted in order to gain some insight into the seakeeping behaviors of the two ships. A generic spring/damper connection was assumed to exist at the interface. Current studies aim at more realistic configurations, along with the establishment of a design and analysis

procedure in order to quantify the performance degradation in a seaway. A simulation model for low frequency motions was also developed, and a comprehensive stability analysis is underway.

THESES DIRECTED:

Nash, C., "Vertical Plane Response of Surface Ships in Close Proximity Towing," Masters Thesis, Naval Postgraduate School, June 2001.

Jones, G., "Semi-Rigid Maneuvering Model for Analysis of Maneuvering in the Horizontal Plane," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Towing, Seakeeping

MECHANISM OF SPRAY GENERATION AT THE FREE SURFACE OF LIQUID JETS

Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: This continuing basic research is an experimental investigation of the ligament and drop formation at the free surface of liquid wall jets, flowing over smooth and sand-roughened plates towards the understanding of the physics of droplet formation, in general, and of the spray formation on bow-sheets, in particular.

SUMMARY: Measurements were made with several high-speed imagers, a pulsating laser, and a Digital Particle Image Velocimeter (DPIV) system and analyzed through the use of appropriate software. The wall-jet Reynolds number ranged from 2.4×10^4 to 4×10^4, the Froude number from 15 to 30, and the Weber number from 1,500 to 3,000. The characteristics of the ligament forest and droplets were determined from the digitized images. Principal Investigator was invited to deliver two papers at two ONR meetings: at CALTECH in April 01 and in San Diego in September 01.

PUBLICATIONS:

Sarpkaya, T. and Merrill, C.F., "Spray Generation from Turbulent Plane Water Wall Jets Discharging into Quiescent Air," *American Institute of Aeronautics and Astronautics Journal*, Vol. 39, No. 7, pp. 1217-1229, July 2001.

Sarpkaya, T. and Merrill, G., "Spray Formation at the Free Surface of Liquid Wall Jets," *Naval Hydrodynamics*, Vol. 22, pp. 145-154, October 1999.

THESIS DIRECTED:

Markle, H.B., "An Experimental Investigation of the Bow Wave on USS Cole (DDG-67)," Masters Thesis, Naval Postgraduate School, September 2001.

Osgood, D.B., "Flow About Perforated Bodies," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Hydrodynamics, Drop Formation, Spray

OPTIMIZATION OF SUBMERGED SENSOR STABILITY

Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Space and Naval Warfare Systems Center - San Diego

OBJECTIVE: To provide expert advice and make recommendations to improve and/or optimize the stability of sensors immersed in earth's magnetic field at the ocean bottom as part of deployable autonomous distributed system (as part of a deployable autonomous distributed system). Review the final report of SNWSC and offer advice for improvement.

SUMMARY: The Space and Naval Warfare Systems Center San Diego (SSC SD) is tasked by the Deployable Autonomous Distributed Systems Demonstration (DADS-D) project to mitigate sensor noise caused by hydrodynamic effects. The immediate concern is the extreme sensitivity of the of fluxgate magnetometers (housed in sea-floor packages) to motion due to surface waves, currents, and the passage of non-naval bodies. This investigator has identified the nature of the relevant hydrodynamic disturbances, the hydrodynamic forces acting on a sensor package, effects of sensor proximity to the seafloor, any data in the literature relevant to the shape of the sensor package, and the frequency phenomena related to vortex shedding and surface waves.

PUBLICATIONS:

Sarpkaya, T., "Final Report to SPAWAR on the Wave-Current Interaction of Fluxgate Magnetometers," August 2001.

Sarpkaya, T., "On the Force Decompositions of Lighthill and Morison," *Journal of Fluids and Structures*, Vol. 15, No. 2, pp. 227-233, Feburary 2001.

Sarpkaya, T., "Hydrodynamic Damping and Quasi-Coherent Structures at Large Stokes Numbers," *Journal of Fluids and Structures*, Vol. 15, No.7, pp. 909-928, 2001.

Sarpkaya, T., "Experiments on the Stability of Sinusoidally Oscillating Flow over a Circular Cylinder," to appear in *Journal of Fluid Mechanics*, Vol. 457, pp. 157-180, 2002.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Sensors, Unsteady Flows, Stability, Frequency Response

REVIEW OF HYDRODYNAMIC LOADS ON SPECIFIC STRAINERS

Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: U.S. Nuclear Regulatory Commission

OBJECTIVE: To review the appropriate topical reports and any other relevant data on hydrodynamic loads on structures submerged in the pressure suppression pools of boiling-water nuclear reactors. The ultimate purpose of these reviews and detailed analyses is to provide sound technical advice to NRC on unsteady flow about specific types of strainers and, in particular, on the prevailing Keulegan-Carpenter numbers and acceleration drag loads so that NRC can perform its regulatory duties in the light of the expert opinion and complete its review of the strainers under their consideration.

SUMMARY: A thorough study of about 3,000-page reports and papers led to the conclusion that the determination of the typical values of the Keulegan-Carpenter number, K, and the acceleration drag coefficient, C_m, for the conditions expected following a loss-of-coolant accident (LOCA) and safety/relief valve (SRV) discharge requires the load carrying capacities (LCCs) of the strainers, the positions of the largest stresses on the strainers and/or their attachments; the velocities, accelerations, (their magnitudes and directions) and their distribution throughout the suppression pool during the first few seconds of LOCA and

SRV. In summary, the existing analyses and experiments are inadequate for the assessment of the safety of the strainers in Boiling-Water Nuclear Reactors. Proper analyses and experiments have been performed to provide sound technical guidance to NRC towards the fulfillment of its regulatory duties.

PUBLICATIONS:

Sarpkaya, T., "Final Technical Evaluation Report to NRC," 25 April 2001.

Sarpkaya, T., "On the Force Decompositions of Lighthill and Morison," *Journal of Fluids and Structures*, Vol. 15, No. 2, pp. 227-233, February 2001.

THESIS DIRECTED:

Osgood, D.B., "Flow About Perforated Bodies," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Nuclear Reactors, Inertial Force, Perforated Bodies, Unsteady Flow

THE WAKE MODELING AND PREDICTION FOR AVOSS

Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration - Langley Research Center

OBJECTIVE: The purpose of the investigation was (a) to develop a new vortex decay model for the prediction of the descent of aircraft trailing vortices subjected to realistic environmental conditions (stratification, turbulence, cross wind, headwind, shear effects, and ground effect), and (b) to apply the model to field data obtained with Lidar in Memphis and Dallas–Fort Worth airports.

SUMMARY: A robust and relatively simple physics-based vortex decay model has been devised. It does not violate any hydrodynamical principles, has only one model constant, uses the turbulence eddy dissipation rate in conjunction with a theoretical model (as verified by experiments and numerical simulations), and it requires no cumbersome algorithms to account for the ground effects. Acquisition of better and more detailed field data (vortex velocities and positions; wind, shear and their gradients; better temperature, humidity, and eddy dissipation profiles), the quantification of the consequences of unstable stratification, and the optimization of the new model parameters constitute the essence of this continuing research of vital international importance. The model has been successfully tested at the Dallas-Fort Worth airport in September 2001. It is now being patented by NASA, (Sarpkaya as one of the four inventors who has devised the theoretical model and carried out the vortex-decay experiments).

PUBLICATIONS:

Sarpkaya, T., Robins, R.E. and Delisi, D.P., "Wake-Vortex Eddy- Dissipation Model Predictions Compared with Observations," *Journal of Aircraft (AIAA)*, Vol. 38, No. 4, pp. 687-692, July-August 2001.

Sarpkaya, T., "New Model for Vortex Decay in the Atmosphere," *Journal of Aircraft (AIAA)*, Vol. 37, No. 1, pp. 53-61, January/February 2000.

Sarpkaya, T., "Resistance in Unsteady Flow: Search for an In-Line Force Model," *International Journal of Offshore and Polar Engineering*, Vol. 10, No. 4, pp. 1053-5381, December 2000.

OTHER:

The model has now been incorporated into NASA's AVOSS program for the management of aircraft landings at large airports (JFK, Memphis, DFW, New Orleans). Sarpkaya is cited as one of the inventors of the model by NASA.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Trailing Vortices, Aircraft Wakes, Wake Hazard

VORTEX BREAKDOWN IN TURBULENT SWIRLING FLOWS
Turgut Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation and Naval Postgraduate School

OBJECTIVE: Vortex breakdown is the transformation of a slender vortex into three-dimensional forms. Where, how, and under what circumstances does this transformation occur in viscous vortical flows constitute the essence of the breakdown problem. Neither a stagnation point, nor a region of reversed flow, nor the bridging of laminar–turbulent states is necessary. Trailing vortices, swirling flows in pipes, vortical flows above sweptback wings at large angles-of-attack, flows in closed containers with a rotating lid, and columnar vortices in atmosphere may experience breakdown. Where, how, and under what circumstances does the breakdown occur in viscous vortical flows constitute the essence of the investigation.

SUMMARY: The definition of the spectral characteristics of the conical region is the subject of the ongoing investigation. The mean velocities and turbulence intensities were measured in forward-scattering mode with a three-component Laser Doppler Anemometer. The results refute the conjectures that the circumstances of breakdown are insensitive to the Reynolds number and the local turbulence properties. These two factors have a strong influence on the evolution of the flow. Of all the known forms, the spiral emerges as the most fundamental breakdown form. All other forms may be regarded as transient states affected by various types of instabilities. At very high Reynolds numbers the breakdown acquires forms and characteristics never seen before: Extremely high rates of revolution, onset of core-bifurcation or core-trifurcation, intense nonisotropic turbulence, and a conical shape.

PUBLICATIONS:

Sarpkaya, T., "Discovery and Evolution of Vortex Breakdown Phenomena," *Progress in AeroSpace Sciences* (in print, 2002).

Novak, F. and Sarpkaya, T., "Vortex Breakdown at High Reynolds Numbers," *American Institute of Aeronautics and Astronautics Journal*, Vol. 38, No. 5, pp. 1671-1679, May 2000.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Vortex Breakdown, Vorticity, Swirling Flow

FRAGMENTATION AND DETONATION OF ANTIPERSONNEL MINE AND SURVIVABILITY OF SENSORS IN THE GRIZZLY
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Sponsor: U.S. Army Tank Automotive Command

OBJECTIVE: The Grizzly has various sensors including control sensors, laser systems, hydraulic lines, wires and various cameras mounted on the Grizzly armor hull which is exposed to various types of landmine detonation. The objective is to study the detonation and fragmentation process of mine such as

OMZ-72 antipersonnel mine and to extend the study on effect of shock wave and fragmentation to the survivability of sensors, laser systems, cameras, wires and hydraulic lines exposed to the threat. Based on the results investigated, NPS will provide design guidance on protecting sensors, laser systems, wires and hydraulic lines, etc, from the threat. The pop-up anti-personnel mines such as the OZM-72 has unique and of interesting features about its horizontal dispersion of fragmentation. The project results will provide design guidance from a better understanding of the threat.

SUMMARY: Many obstacles such as minefields, barbwire entanglements, tank ditches and other fortifications are used to paralyze the forward momentum of mechanized armed forces. To combat this the Grizzly tracked vehicle was developed for the United States Army to defeat these complex obstacles and clear mine fields. Due to its intended mission various sensors, laser systems, hydraulic lines, wires and cameras are mounted on the armor hull, which are exposed to various types of landmine detonation and fragmentation.

This study is to model an OZM – 72 bounding antipersonnel mine to be used in studying the effects of shock waves and fragmentation on the survivability of the equipment mounted on the Grizzly's armored hull. 2D and 3D finite element models of the antipersonnel mines are developed and used to simulate the detonation and fragmentation phenomena. The analysis results obtained from the models provide a basis from which design guidance can be formulated for protecting equipment or personnel from this threat.

PUBLICATIONS:

Kloster, M.S. and Shin, Y.S., "Modeling and Simulation of Detonation and Fragmentation of Anti-Personnel Mine," *Proceedings of 72nd Shock and Vibration Symposium*, Destin, FL, 12-16 November 2001.

THESES DIRECTED:

Kloster, M.S., "Coupled Lagrangian and Eulerian Approach to Detonation and Fragmentation Problems," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: ALE Analysis, Fragmentation and Detonation, Land Mine

IMPACT ANALYSIS AND ACTIVE VIBRATION DAMPING ON ORBITAL VEHICLES

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Sponsor: National Aeronautics and Space Administration - Dryden

OBJECTIVE: To develop a method to determine the location, force, and orientation of an impact on a space truss using a minimal distributed sensor grid. Also achieve improved active control of vibrations induced in the truss by installed equipment operating at a constant frequency. The active control is to be achieved using piezoelectric elements installed as truss members and should be able to control the vibration at multiple nodes and sensitive to various axis without relocating the active elements. A FEM of the truss, generated using ANSYS, is to be used to assess the ability to model the implementation of the control algorithm and will be compared to the actual experimental results.

SUMMARY: As spacecraft designs become more complex, compact, and lightweight, it becomes more likely that equipment induced vibrations will adversely affect other components. The use of either passive or active damping typically requires extensive system modeling and a significant weight addition. The Adaptive Multi-Layer LMS Controller, coupled with piezoelectric active elements has been able to suppress single axis vibration of a truss by greater than 50 dB. The algorithm has also proven to be flexible with respect to actuator orientation and location with respect to the desired point of suppression. The test platform was the NPS space truss, which is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment mounted at its extremities. One of two installed piezoelectric actuators and an

Adaptive Multi-Layer LMS control law were used to effectively eliminate an axial component of the vibrations induced by a linear proof mass actuator mounted at one end of the truss.

PUBLICATION:

Barney, T.A., Shin, Y.S., and Agrawal, B.N., *Adaptive Multi-Layer LMS Controller Design and Application to Active Vibration Suppression on a Truss and Proposed Impact Analysis Technique*, Naval Postgraduate School Technical Report, NPS-ME-01-002, June 2001.

THESIS DIRECTED:

Barney, T., "Impact Analysis and Active Vibration Damping on Orbital Vehicles," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

KEYWORDS: Space Truss, Active Vibration Damping, Piezoelectric Elements, Impact Analysis, ANSYS, FEM Simulation of Active Control Method